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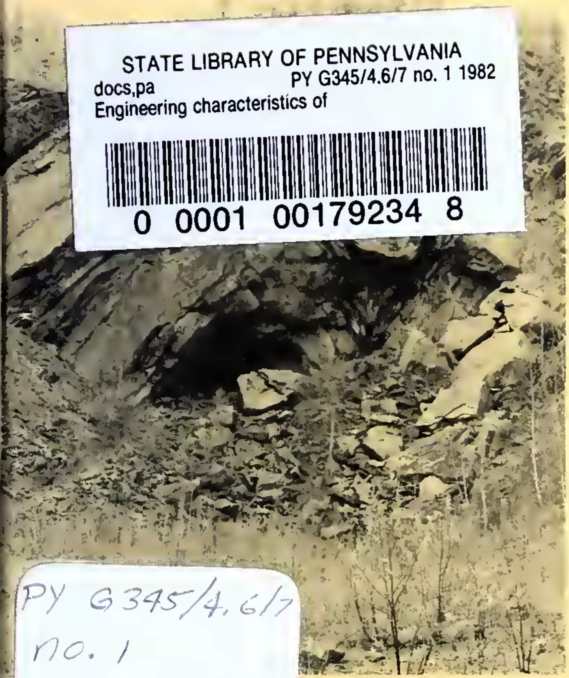

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Environmental Geology Report 1

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ENGINEERING CHARACTERISTICS OF THE ROCKS OF PENNSYLVANIA

Alan R. Geyer
J. Peter Wilshusen

DEPARTMENT OF
ENVIRONMENTAL RESOURCES
OFFICE OF RESOURCES MANAGEMENT
BUREAU OF
TOPOGRAPHIC AND GEOLOGIC SURVEY
Arthur A. Socolow, State Geologist

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Environmental Geology Report 1

ENGINEERING CHARACTERISTICS OF THE ROCKS OF PENNSYLVANIA

Environmental Geology Supplement to the State Geologic Map

by Alan R. Geyer and J. Peter Wilshusen
Pennsylvania Geological Survey

PENNSYLVANIA GEOLOGICAL SURVEY

FOURTH SERIES

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PREFACE

Geologists have an important role to play in improving and protecting our environment. Geologic analysis will assist in defining the most effective use of our land, and its potential for resource development, industrial utilization, housing, agriculture, and recreation. Geologic data will aid in locating sources of quality groundwater to augment public and industrial needs, as well as define areas where groundwater can be stored and reused. It is geologic data that will define where it is safe and where unsafe to dispose of solid and liquid wastes. Geologic evaluation will define hazardous conditions such as landslide and subsidence areas, and provide solutions to many of these problems.

The Pennsylvania Geological Survey, through emphasis of the relevance of its geologic investigations to the needs of Pennsylvania, is pleased to be making a contribution to better environmental planning and development.

ARTHUR A. SOCOLOW

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ENGINEERING CHARACTERISTICS OF THE ROCKS OF PENNSYLVANIA

by

Alan R. Geyer and J. Peter Wilshusen

INTRODUCTION

This publication outlines important engineering, hydrologic, and geologic characteristics of the rocks of Pennsylvania as they affect engineering and construction projects and important land use decisions. It is intended that this publication be used as a supplement to the 1980 edition of the Geologic Map of Pennsylvania. The names of the rock formations listed herein correspond to those used on the map.

Summarized information for each rock unit is designed to aid in initial site investigations, as well as to serve as a basis for regional and local land use planning.

The report is broad in scope, and the authors do not attempt to cover all local variations in the characteristics of the individual rock formations. No attempt is made to provide the site-specific information that is obtained from on-location sampling, investigation, and laboratory analyses; the latter are normally performed as part of the design of any specific structure or prior to any final land use decision. The summary of engineering characteristics of each rock formation in Pennsylvania includes descriptions of important observable geological factors; these should provide a basis for preliminary land use and construction planning. It is hoped that this publication will provide the reader with a visual impression, the overall geometry, and the engineering behavior of each rock body described.

Porosity, permeability, and characteristic groundwater information have been taken from detailed groundwater studies published by the Pennsylvania Geological Survey and from sub-basin reports of the State Water Plan. Wherever possible, yield and quality evaluations also have been obtained from the above sources. Where no prior studies have been conducted on a particular aquifer or where an aquifer may have been grouped with several others in the State Water Plan, it is so stated in this text.

Every attempt was made to obtain a wide distribution, as well as a statistically significant number of exposures, for each rock formation. Geologic factors studied involved qualitative and quantitative observations. In many instances, photographs are presented to illustrate one or more of the factors evaluated. A limited amount of laboratory test data are included. These data were gathered from published and unpublished material and from communications with geologists and engineers most familiar with particular rock formations.

ACKNOWLEDGEMENTS

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The authors gratefully acknowledge the critical review of the manuscript by Dr. Arthur A. Socolow, the State Geologist, and express deep appreciation for the time and experience given by Dr. Jesse L. Craft and William B. Barber during all phases of this project.

MAJOR ENGINEERING CHARACTERISTICS OF ROCKS

CUT-SLOPE STABILITY

One of the most difficult problems in engineering geology is to determine the factor of safety of a slope, either a natural one or one that man has altered. These problems are extremely complex because the rock mass is highly variable. The composition of the rock, bedding planes, joint surfaces, cleavage planes, and faults are inherent variables that contribute to the dilemma. This situation is further complicated by the change of these variables with time, which can, for example, increase rock weathering and further reduce slope stability. Man-made slopes are often designed on the basis of the general quality of the rock type, rather than the total characteristics of the rock formation at a particular location. The basis for slope selection is frequently the designer's experience with general rock types such as sandstone, shale, or limestone. However, some slope failures have resulted because of bedding planes, joints, or faults that dip into the excavation, even though the rock lithology is one that performs satisfactorily under other circumstances.

The rock excavation shown in Figure 1 removed the ''toe'' of the slope and thus removed the buttressing effect of the rock that was originally present. As a result, the stability of this slope was dependent entirely upon the shearing resistance of the bedding and joint planes. Unfortunately, in this case, the shearing resistance was not sufficient, and the slope failed. In situations where the steepness of the cut face is flatter than the dip of the bedding or fractures, or the bedding is nearly horizontal and the fractures are very widely spaced, or the bedding is dipping away from the excavation or at a right angle to the excavation, there usually is no massive failure.

Groundwater is another variable that affects slope stability. In the case shown in Figure 1, the force exerted by groundwater, combined with the force of gravity, contributed toward the failure of the slope.

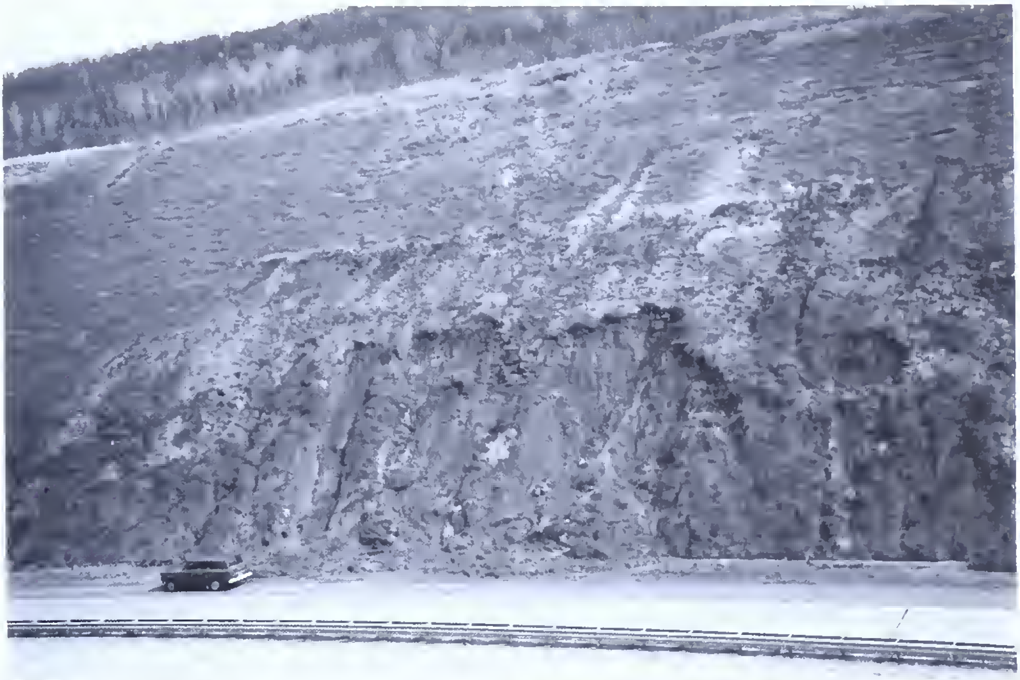


Figure 1. Landslide in colluvium near the base of Brush Mountain, entrance ramp to U. S. Route 220 at Charlottsville, 2 miles southwest of Tyrone, Blair County.

Groundwater, through its occurrence and movement in joint and bedding planes, acts as a lubricant and causes a decrease in the frictional shearing resistance by reducing the normal resistance across the walls of the joint and bedding surfaces.

The lithology of the rock formation may be another extremely important factor in slope stability. The Pittsburgh red beds of western Pennsylvania, for example, is a sequence of claystones (indurated clay) that are abnormally susceptible to landsliding. Figure 2 shows a house underlain by weathered Pittsburgh red beds. This rock unit is not laminated, fractures irregularly, and when weathered breaks into small, randomly shaped fragments. Streaks, zones, and other near-planar concentrations of expandable clay minerals which may drastically affect the formation's engineering performance are present in most places. Detailed studies of the clay mineralogy of this formation and others like it are needed to learn the distribution and origin of these expandable-lattice, highly mobile clays in order to be able to predict failure-prone slopes.

EASE OF EXCAVATION

Rock properties, more than other factors, determine the degree of difficulty and the cost of excavation. The method of excavation to be used is

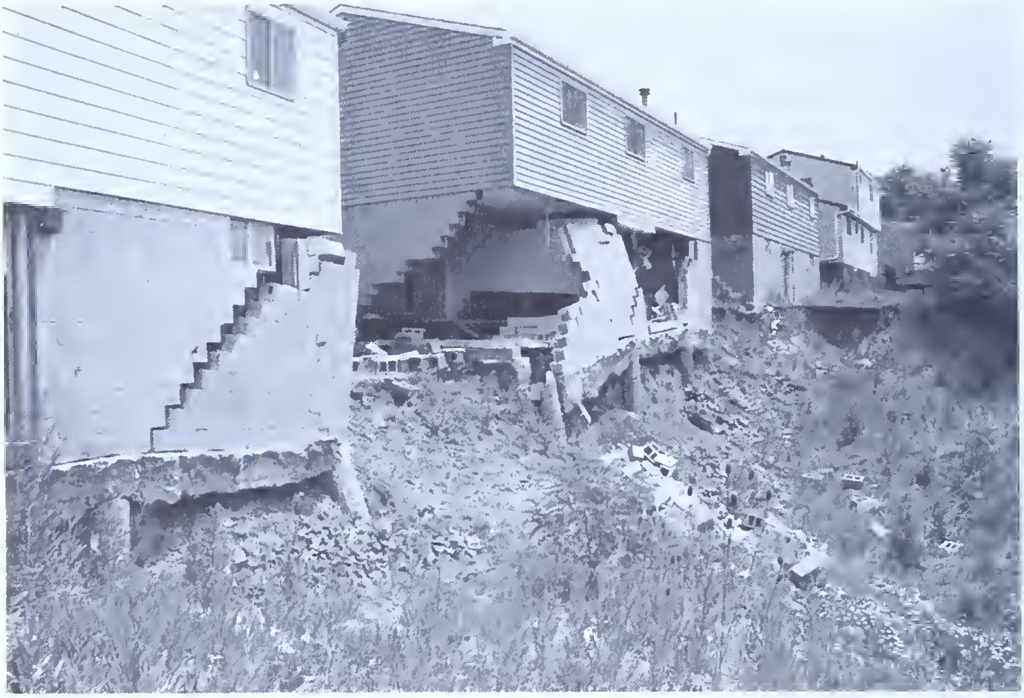


Figure 2. Shaler Township slide, Height Drive, Allegheny County, in red clay shales of the Casselman Formation, Conemaugh Group.

often dictated by the geologic conditions expected, and the cost of excavation is directly related to the method.

Where a rock formation is exposed at the surface, its composition, weathered condition, and the orientation and spacing of joints, faults, and bedding planes may be determined. At depth, however, techniques such as core boring, combined with borehole photography, may be used to delineate these properties. Primarily, it is a combination of the specific rock properties that determines how difficult the rock mass will be to excavate.

In the descriptions of rock formations presented in this report, the "ease of excavation" comments are relative. An unconsolidated, surficial sand and gravel deposit of glacial origin in northwestern Pennsylvania may be excavated quite easily with light power equipment. However, a massive, slightly fractured, unweathered diabase in southeastern Pennsylvania will require considerable blasting.

Geological explorations sufficient for design and specification purposes should be conducted before making the excavation. Where underground excavations are to be located at great depths or where open excavations are to extend for some distance, the rock summaries described in this publication under "ease of excavation" should prove of particular help in the initial phase of a study.

FOUNDATION STABILITY

An increase in urban and suburban sprawl onto unstable land has focused people's attention on possible geologic hazards and particularly on the foundation stability of rocks.

For over a hundred years, geologic maps, reports, and charts have indicated where coal has been mined beneath the land surface, the location of springs, marshes, floodplains, caves, sinkholes, disappearing streams, peat bogs, quicksand, quick clays, and other potentially unstable foundation conditions. However, even today, the average property owner or developer is taken completely by surprise when trouble appears.

Limestone and dolomite (carbonate rock) areas of the Commonwealth are widespread and represent a potentially serious foundation problem. The solubility of these carbonate rocks often makes small fractures become large channelways; intersecting fractures become huge chambers and the normally smooth soil-bedrock interface becomes pinnacled (see Figures 3 through 5). In many areas these features are hidden from view beneath a gently rolling landscape with exceptionally rich looking soil.

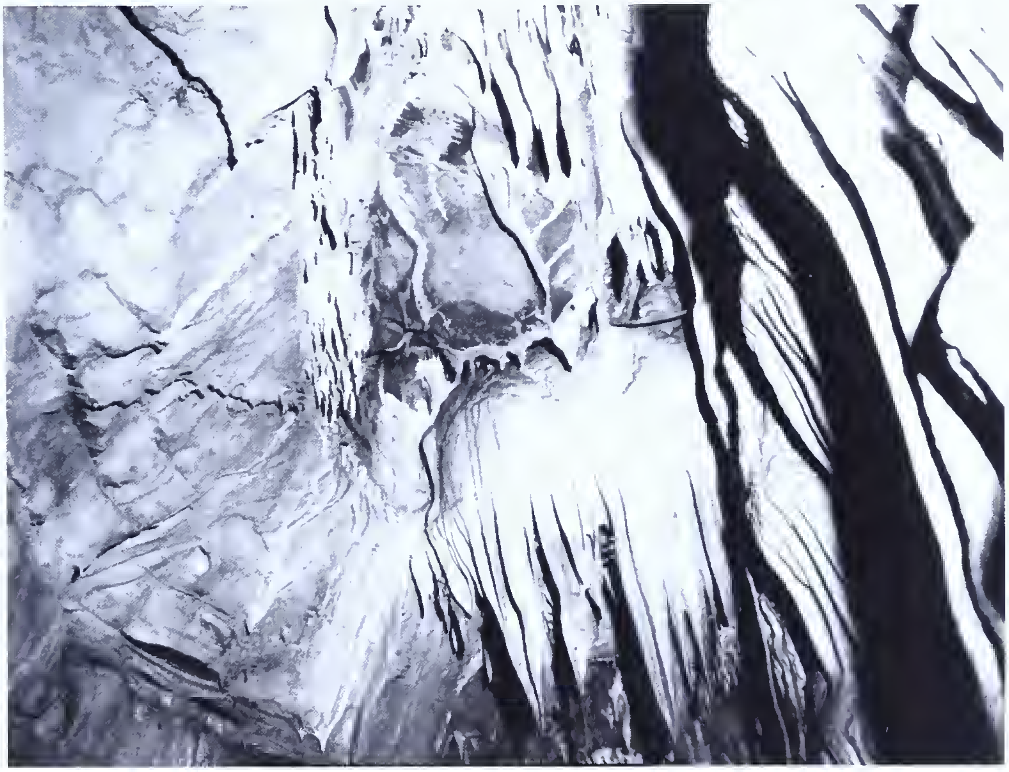


Figure 3. Grand ballroom in cave at intersection of two joint surfaces, Epler Formation, Indian Echo Cave, Dauphin County.

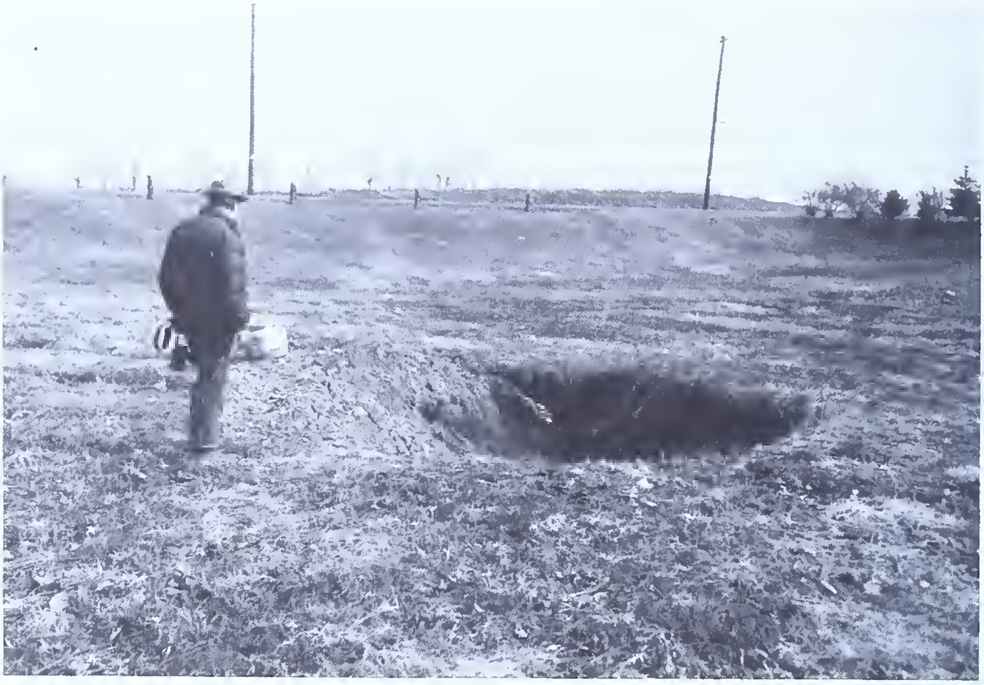


Figure 4. Sinkhole along U. S. Route 322, Derry Township, Dauphin County.

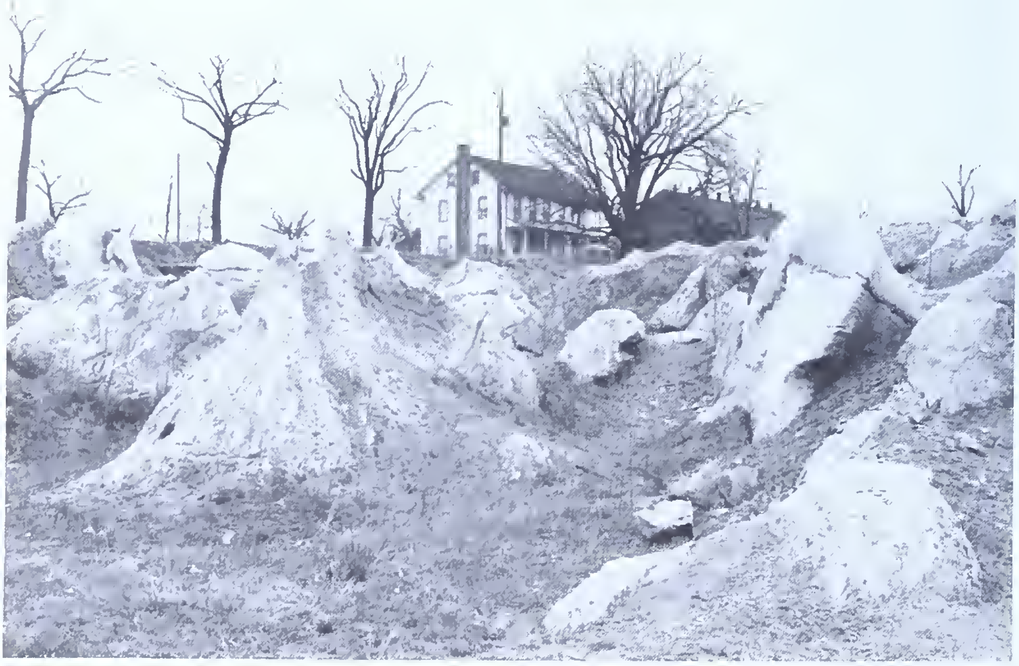


Figure 5. Limestone pinnacles at the soil-bedrock interface, Lancaster County.

Figure 6 shows graphically the sequence of development of many sinkholes; these are surface depressions from a few feet to hundreds of feet in diameter which may develop catastrophically or over an extended period of time. Throughout Pennsylvania, the character of the carbonate bedrock surface is usually pinnacled, and covered with a thick, weathered soil mantle which dries out during periods of drought or by lowering of the water table by pumping. Volume shrinkage of the soil takes place.

This shrinkage is irregular and may be expressed at the surface by the typical rolling topography of carbonate terrains. However, an open void may develop beneath the surface of this overlying debris, and the roof of the void assumes the shape of an arch. The weight of the compacted soil is sustained by the arch-bridge until some trigger mechanism, such as a heavy rain or a strong vibration, causes the arch to collapse. In other cases the arch is of bedrock, and, as a subsurface solution cavity grows larger, the rock roof collapses to form a surface sinkhole.

No simple solution is available for the detection of potential sinkholes or determining the exact soil-bedrock interface. Standard foundation exploration techniques such as core drilling are often inadequate. Geophysical methods show some promise. New techniques have yet to be proven. The unexpected should be anticipated. Design criteria, construction methods, and project schedules should be flexible to allow for day-by-day changes. An awareness that severe foundation stability problems may exist in carbonate bedrock is most important.

As a result of extensive coal mining in the anthracite and bituminous coal fields of Pennsylvania, very real man-made subsidence problems exist. Many surface structures located over old, mined-out coal beds have suffered substantial subsidence damage (Figure 7).

In general, the occurrence of mine subsidence is related to the size and spacing of coal pillars remaining in the mined-out area, the rock and its characteristics above and below the mined-out coal, the thickness of the rock zone over the coal horizon, and fluctuations in groundwater levels. Engineering geologists familiar with coal-mine subsidence state that damage to single-story structures is not common over old, inactive mines where the overlying rock cover exceeds 100 feet. The same opinions have been given for heavier structures where the overlying rock cover exceeds 200 feet. In both cases, the overlying cover consists of at least 90 percent rock.

In areas of active mining, the most positive means of preventing subsidence damage is to leave coal pillars in place to support the ground surface and to backfill the voids. When structures are to be built over old mines where there is only a shallow rock cover, an extensive investigation is required. After such a thorough study, the method that is designed to support a structure is a function of the cost and the acceptable degree

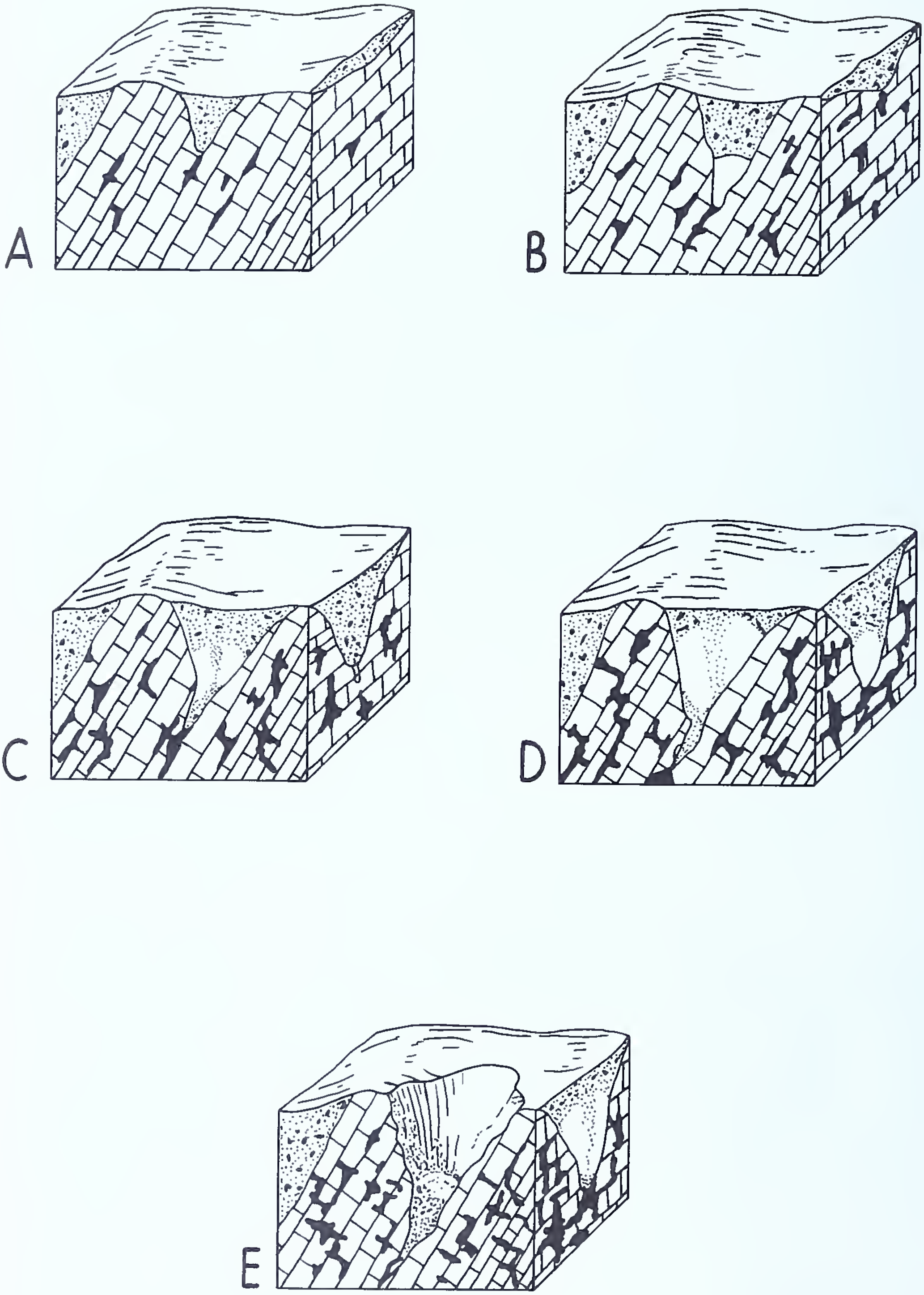
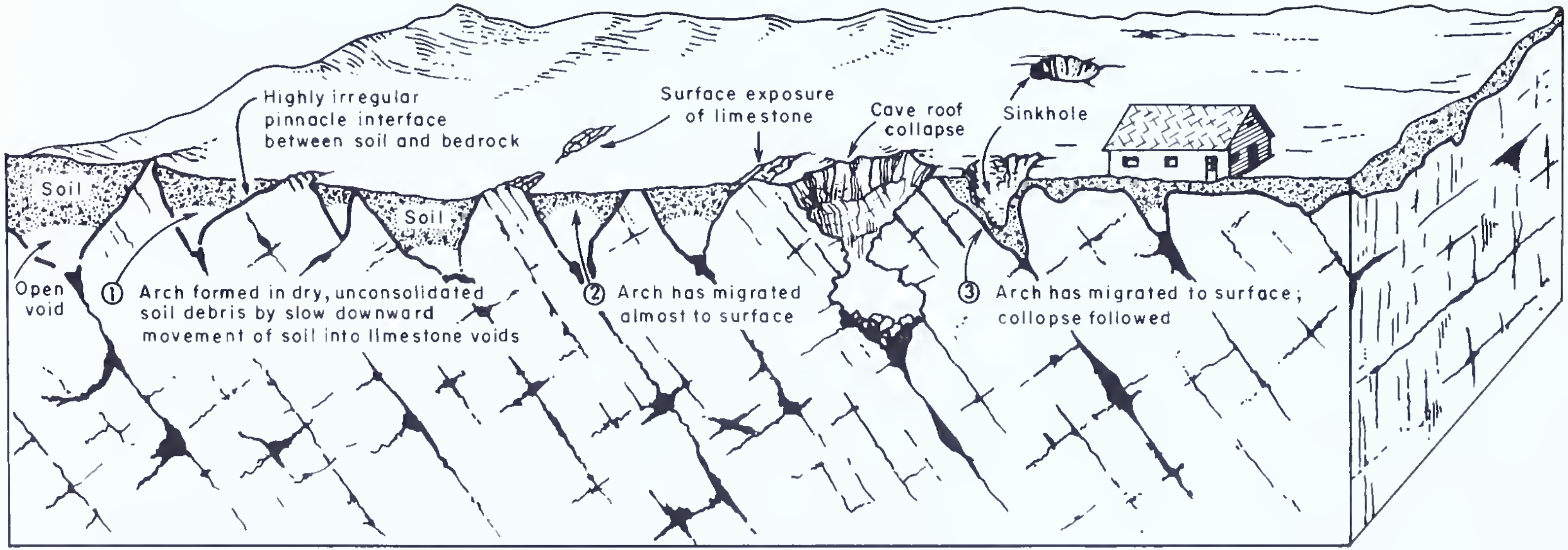


Figure 6. Sequential development of sinkhole by soil collapse.


Highly irregular pinnacle interface between soil and bedrock
Surface exposure of limestone
Cave roof collapse
Sinkhole
Soil
Soil
Open void
① Arch formed in dry, unconsolidated soil debris by slow downward movement of soil into limestone voids
② Arch has migrated almost to surface
③ Arch has migrated to surface; collapse followed

Hypothetical cross section through a carbonate valley showing stages of development of sinkholes.

At (2) above, any sudden influx of water from natural rainfall or from man's activities could saturate the soil, causing increased weight on the arch, decreased interparticle friction holding the arch together, and ultimate sudden collapse.

Groundwater table is highly irregular and not shown.

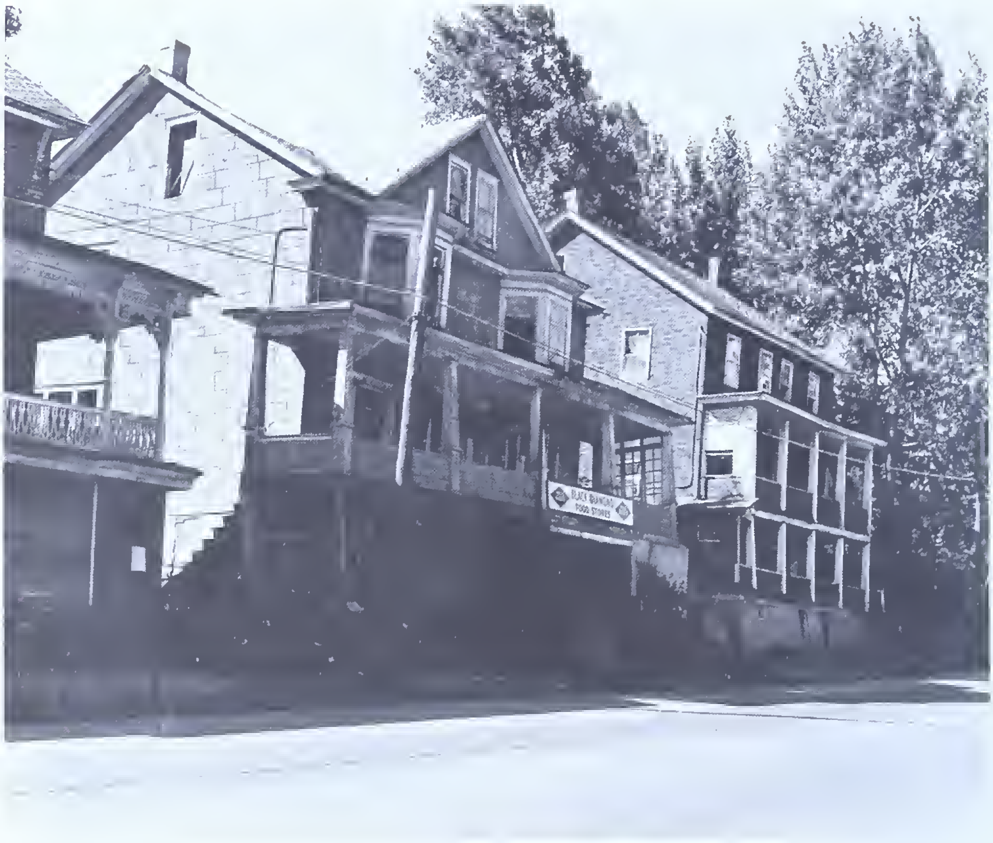


Figure 7. Result of mine subsidence in northeastern Pennsylvania.

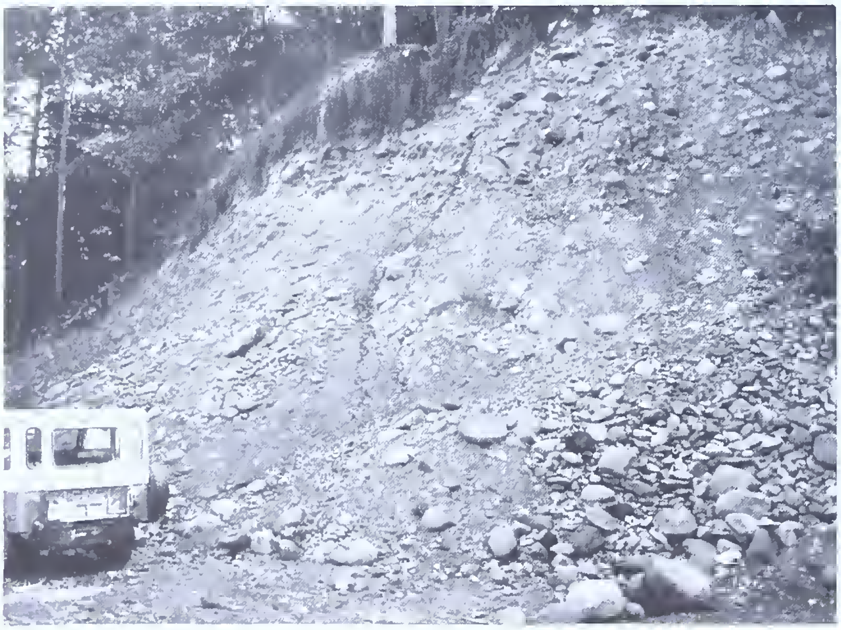


Figure 8. Glaciofluvial outwash gravel, south side of Pa. Route 87, Barbours quadrangle, Lycoming County.

of risk. Common support methods in use today include grouting, construction of concrete piers within the mine, drilled piers, subsurface stabilization utilizing grout column construction, and filling of mine voids.

Surface lands underlain by mined-out coals and carbonate terrains in Pennsylvania are the areas that have the largest number of foundation problems and thus receive the most attention. However, other areas throughout the Commonwealth and other geologic terrains warrant special concern. Included in this group are: 1) the thick deposits of glacial till and outwash found primarily in northwestern and northeastern Pennsylvania (Figure 8); 2) peat bogs and related swamps of quicksand also found mostly in northwestern and northeastern Pennsylvania; and 3) the floodplains associated with most rivers, streams, and creeks across the state (Figure 9). The geological materials present in each of these areas and features mentioned are often unstable and present foundation hazards.

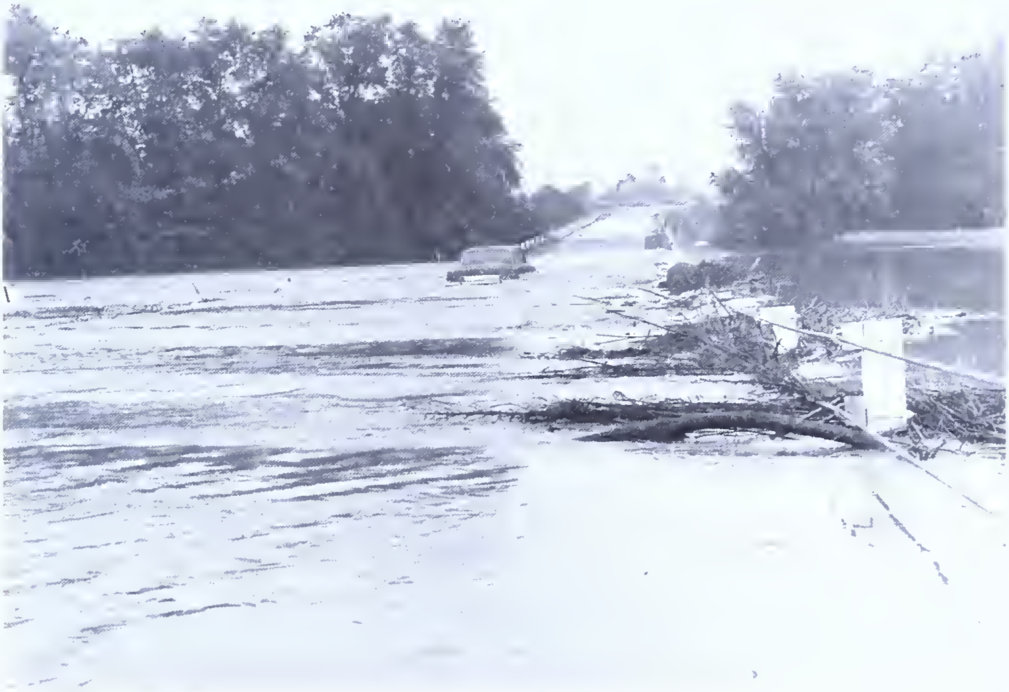
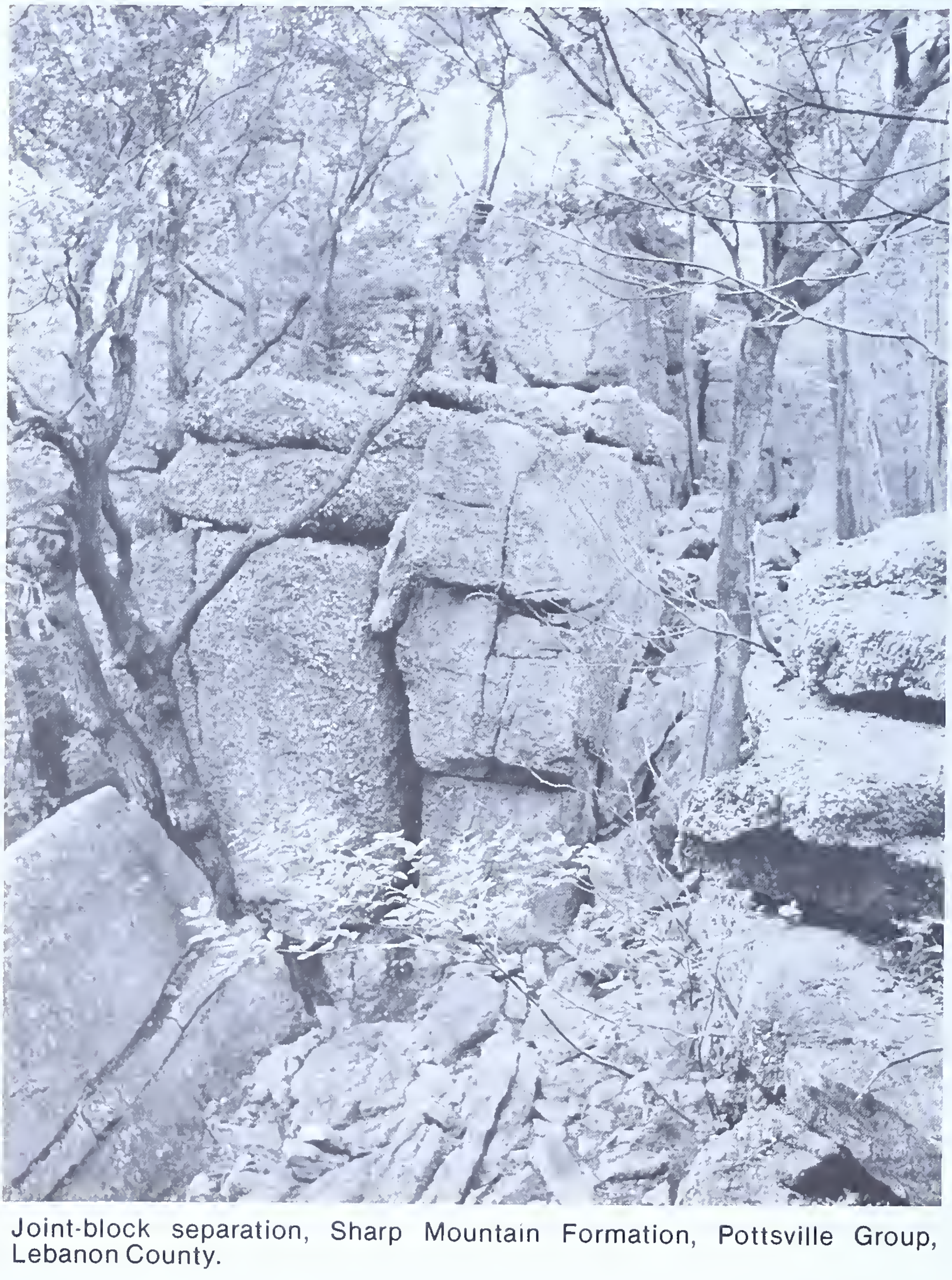


Figure 9. Floodplain along Swatara Creek, Sand Beach Road, Derry Township, Dauphin County.

ENGINEERING CHARACTERISTICS OF ROCK FORMATIONS IN PENNSYLVANIA



Joint-block separation, Sharp Mountain Formation, Pottsville Group, Lebanon County.

EXPLANATION OF SEMIQUANTITATIVE TERMS AND MISCELLANEOUS CHARTS

BEDDING

Thickness
Fissile =<1/2″
Thin = 1/2″-2″
Medium = 2″-2′
Thick = 2′-4′
Massive =>4′

Attitude
Horizontal = 0°-5°
Gently inclined = 5°-20°
Moderately inclined = 20°-45°
Steeply inclined = 45°-85°
Very steeply inclined = 85°-90°

FRACTURING

Joint spacing (after Deere, 1963)
Very widely spaced =>10′
Widely spaced = 3′-10′
Moderately spaced = 2′-3′
Closely spaced = 2″-2′
Very closely spaced =<2″
Inclination
Same as bedding attitude.
Joint openings (after British Geological Society, 1977)
Wide =>200 mm
Moderately wide = 60-200 mm
Moderately narrow = 20-60 mm
Narrow = 6-20 mm
Very narrow = 2-6 mm
Extremely narrow =>0-2 mm
Tight = 0 mm

WEATHERING

Description (after Hofmann, 1973)
Depth
Deep =>4′
Moderate = 1′-4′
Shallow =<1′
Shape
Weathered material
Mantle thickness
Thick =>30′
Moderate = 5′-30′
Thin = 0′-5′

Completely weathered—Chemical decomposition is nearly complete; more chemically resistant minerals may still be visible; rock fabric is visible; heavily iron stained or completely bleached throughout; cohesion of particles is reduced to the extent that the material can be crumbled with fingers.

Highly weathered—Weathering is advanced; bleached or iron stained throughout; joints are heavily iron stained and/or clay filled.

Moderately weathered—Some evidence of weathering of rock fabric; commonly slightly bleached; heavily iron stained on almost all joints.

Slightly weathered—Incipient weathering along joint planes; some joints are lightly iron stained; no weathering of rock fabric.

Fresh—Unweathered.

TOPOGRAPHY

Steepness of natural slopes

Gentle = 0°-5°
Moderate = 5°-15°
Fairly steep = 15°-45°
Steep = 45°-80°
Very steep = 80°-89°
Vertical = 90°

POROSITY AND PERMEABILITY

Low—Essentially impermeable; coefficient of permeability (K) probably approaches zero, except in zones of open joints, fractures, bedding planes, and solution channels. In these cases, appreciable flow of water may be encountered.

Moderate—Coefficient of permeability (K) is probably less than 50 × 10^{-4} cm/sec (14 ft/day), except where open planar elements or voids occur having appreciable flow of water.

High—Coefficient of permeability (K) for the most part is probably greater than 50 × 10^{-4} cm/sec (14 ft/day). In coarse alluvium, K may exceed 3,000 × 10^{-4} cm/sec (847 ft/day). In cavernous limestone very rapid flow of water can occur.

EASE OF EXCAVATION

Easy—Can be excavated by hand tools or lightweight power equipment. Some large boulders may require drilling and blasting for their removal. Dewatering and bracing of excavation walls may be required.

Moderately easy—Rippable by heavyweight power equipment at least to weathered-rock/fresh-rock interface and locally to greater depths.

Intermediate—Rippable by heavyweight power equipment to depths chiefly limited by the maneuverability of equipment. Hard rock layers or zones of hard rock may require drilling and blasting.

Moderately difficult—Requires drilling and blasting for most deep excavations, but locally may be ripped to depths of several feet due to closely spaced joints, bedding, or weathered rock.

Difficult—Requires drilling and blasting in most excavations, except where extensively fractured or weathered.

CUT-SLOPE STABILITY

Good—Rocks have been observed to stand in vertical cuts where jointing and faulting are at a minimum. However, where moderately close jointing or faulting is common, slopes not steeper than 3:1 (vertical:horizontal) have been seen. In cuts higher than 50 feet, debris-catching benches are used.

Fair—Cut slopes ranging from 2:1 to 1:1 have been observed; flatter where rocks are intensely jointed or fractured. Rockfall may be frequent if steeper cuts are made. Locally, lenses of harder rock may permit steeper cuts, provided jointing and fracturing are at a minimum. Benching has been observed in cuts higher than 30 feet.

Poor—Slopes of 1:1 or flatter have been observed. These deposits commonly exhibit a deceptive temporary stability, sometimes standing on vertical or near-vertical cuts for periods ranging from hours to more than a year. However, ultimate and sudden failure is virtually assured with such steep slopes.

FOUNDATION STABILITY

Good—Bearing capacity is sufficient for the heaviest classes of construction, except where located on intensely fractured zones or solution openings.

Fair—Choice of foundation styles is largely dependent on weathering depth, rock composition, and relation to the water table.

Poor—If stabilized, may provide sufficient bearing capacity for light or moderate construction.

CONSTRUCTION MATERIALS

Quality as source of road material:

- Excellent—Shape of broken rock is commonly satisfactory for packing. Strength is excellent; good resistance to abrasion. Heavy wear on crushing equipment. Possibilities of alkali-aggregate reaction should be investigated.
- Good—(A) Shape of broken rock locally may be elongate, yielding low packing efficiency. Strength is excellent; good resistance to abrasion. Heavy wear on crushing equipment. Possibilities of alkali-aggregate reactions should be investigated. (B) Shape of broken rock is satisfactory for packing. Strength is good; fair resistance to abrasion. Light to moderate wear on crushing equipment.
- Fair—(A) Slight weathering may cause incipient granulation to depth of several tens of meters, so coarse aggregate may be only a small part of crushing product. Shape of broken rock is generally satisfactory for packing. Strength good; fair resistance to abrasion. Moderate wear on crushing equipment. (B) Screening and washing are required. Locally, the presence of large boulders and cobbles requires crushing or selective pit work. Strength and resistance to abrasion are variable because deposits may contain a heterogeneous mixture of rock fragments.
- Poor—(A) Contains large quantities of clay or friable rock. Strength is poor; little resistance to abrasion. (B) Shape of broken rock is probably largely unsatisfactory for packing. Strength is excellent; good resistance to abrasion. Heavy wear on crushing equipment.

Suitability as source of riprap and building stone:

- Good—Durable high-density rock having joints commonly spaced sufficiently far apart to allow consistent removal of large blocks and from which blocks for shaping probably could be quarried without undue difficulty.
- Fair—Rock is otherwise suitable but commonly has one or more of the following deleterious characteristics: (A) rock is only moderately durable; (B) rock has unsatisfactory separation characteristics; (C) rock is only available in limited quantities.
- Poor—Largely rock of relatively poor durability.

Quality as source of fill:

Good—Material that when quarried will contain, in addition to coarse fragments, an appreciable portion of clayey fines as binder.

Fair—Material that when quarried and crushed probably would require blending, but is otherwise satisfactory.

Poor—Material that would be difficult to upgrade to a suitable product.

ROCK TEST DATA

Engineering classification of intact rock (after Deere and others, 1967)

Uniaxial compressive strength (lb/in^2)

>32,000 = very high strength
16,000-32,000 = high strength
8,000-16,000 = medium strength
4,000-8,000 = low strength
<4,000 = very low strength

Uniaxial compressive strength (lb/in^2)

>500 = high modulus ratio
200-500 = average (medium) ratio
<200 = low modulus ratio

Bearing capacity (tons/ft^2)

<1 = very poor
1-4 = poor
4-8 = fair
8-32 = good
>32 = excellent

Relationship of Rock Quality Designation (RQD) to overall rock quality

(Rock Quality Designation is determined by counting only those pieces of core that are 4 inches (10 cm) in length or longer and that are hard and sound [after Deere and others, 1967].)

Rock Quality Designation		Description of rock quality
0- 25%	=	very poor
25- 50%	=	poor
50- 75%	=	fair
75- 90%	=	good
90-100%	=	excellent

Summary of Physical Properties of Common Rocks

Rock type	Unit dry weight lb/ft^3	Unconfined compressive strength lb/in^2	Tensile strength (1) lb/in^2	Shear strength		No. of projects represented	Source
				Angle of internal friction (°)	Cohesion lb/in^2		
Shale	134-165	30- 1,000	250-1,480	6-33	95-1,500	12	Mellinger (1969)
		1,000- 2,950					
Silty shale	145-169	370- 1,000	720-3,200	10-54	200-1,970	13	Do.
		1,000- 6,300					
Sandy shale	154-167	4,850-13,580	1,400-3,140	29-60	310-2,660	7	Do.
Indurated clay	131-170	55- 1,000	790-1,090	10-60	18- 600	11	Do.
		1,000- 3,520					
Claystone	148-164	420- 1,000		24-60	0- 600	4	Do.
		1,000- 6,000					
Siltstone	149-166	2,000-11,300	1,380-3,160	19-48	590-2,930	10	Do.
Granite		23,000-42,600					Bolz and Tuve (1973)
Basalt		11,800-52,000					Do.
Marble		6,700-34,500					Do.
Gneiss		22,200-36,400					Do.
Quartzite		21,100-91,200					Do.
Limestone		5,300-37,600					Do.
Sandstone		4,800-34,100					Do.

Tests on Pennsylvania Stone for Highways

(From Stone (1932, p. 18); compiled from records of tests made under the direction of
H. S. Mattimore by the Testing Laboratory, Pennsylvania Department of Highways)

Kind	Operator	Quarry location	County	Weight lb/ft^3	Absorption lb/ft^3	Crushing strength lb/in^2
Limestone	American Limestone Co.	Bellefonte	Centre	167.9	0.17	28,528
Do.	Bessemer Limestone & Cement	Beaver	Beaver	169.1	0.50	19,733
Do.[1]	Booth & Flinn	Bakers Station	Westmoreland	167.9	0.39	33,512
Do.	Duncansville Lime & Stone Co.	Duncansville	Berks	171.1	0.17	19,740
Do.	Fehr & O'Rourke	Shillington	Blair	169.0	0.23	18,245
Do.	Hoffman Bros. & Wilson	Paxtang	Dauphin	171.1	0.27	17,129
Do.	do.	do.	do.	175.3	0.19	25,579
Do.	Lemoyne Quarries Co.	Lemoyne	Cumberland	171.1	0.09	20,378
Do.[2]	Lukens & Yerkes	Henderson	Montgomery	174.2	0.44	12,875
Do.	Mapleton Lime & Stone Co.	Mapleton	Huntingdon	169.0	0.13	33,222
Do.	do.	do.	do.	169.0	0.05	21,543
Do.	Milliard, Harry	Myerstown	Lebanon	168.4	0.33	22,052
Do.	New Castle Lime & Stone Co.	Hillsville	Lawrence	170.4	0.31	15,776
Do.	Northampton Quarry Co.	Northampton	Northampton	173.6	0.21	24,726
Do.	do.	do.	do.	167.8	0.25	20,811
Do.	Penn Lime & Stone Co.	Rheems	Lancaster	174.2	0.26	25,514
Do.	do.	do.	do.	171.7	0.19	28,049
Do.	Pine Creek Lime & Stone Co.	Jersey Shore	Lycoming	166.6	0.37	23,152
Do.	Stacy Wilton	Bittinger	Adams	171.7	0.45	18,636
Do.	Templeton Limestone Co.	Templeton	Armstrong	162.2	1.62	17,277
Do.	Warner, Charles Co.	Cedar Hollow	Chester	178.4	0.42	28,049
Do.	Whiterock Quarries	Pleasant Gap	Centre	167.2	0.15	24,053
Sandstone	Basalt Trap Rock Co.	Alexandria	Huntingdon	164.7	1.07	21,718
Do.	General Crushed Stone Co.	White Haven	Luzerne	169.1	0.17	23,718
Do.	Kibblehouse, Ralph T.	Perkiomenville	Montgomery	172.3	0.36	33,077

Tests on Pennsylvania Stone for Highways (Continued)

Kind	Operator	Quarry location	County	Weight lb/ft^3	Absorption lb/ft^3	Crushing strength lb/in^2
Do.	Susquehanna Stone Co.	Dalmatia	Northumberland	167.9	0.24	35,903
Do.[3]	Vang Construction Co.	Casparis	Somerset	166.0	0.50	19,806
Do.	Water Street Trap Rock Co.	Water Street	Huntingdon	164.7	0.74	19,052
Gneiss	Bethayres Quarry Co.	Bethayres	Montgomery	168.5	0.29	16,915
Do.[4]	Devault Stone Co.	Devault	Chester	175.3	0.16	23,978
Do.	do.	do.	do.	189.1	0.19	26,804
Do.[5]	General Crushed Stone Co.	Glen Mills	Delaware	186.0	0.05	27,018
Do.	Keystone Trap Rock Co.	Cornog	Chester	181.6	0.45	45,074
Diabase	Dyer, John T. Company	Birdsboro	Berks	183.5	0.17	17,086
Do.	do.	do.	do.	186.0	0.30	32,063
Do.	do.	do.	do.	183.5	0.64	28,108
Do.	do.	do.	do.	184.1	0.33	21,414
Do.	do.	do.	do.	183.5	0.33	19,530
Do.	do.	do.	do.	181.6	0.27	18,531
Do.	General Crushed Stone Co.	E. Rockhill	Bucks	189.1	0.28	27,832
Do.	do.	do.	do.	187.2	0.11	21,573

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[1] Siliceous limestone.

[2] Dolomitic marble.

[3] Calcareous sandstone.

[4] Granite gneiss.

[5] Hornblende gneiss.

The summary statements on the following pages are based on field observations in road excavations, bridge abutments, railroad rights-of-way, quarries, and natural exposures throughout the Commonwealth. To these observations have been added information on actual service records supplied by geologists and engineers. Rock test data presented are mainly from intact core or block samples, which may or may not be representative of the rock mass. These summary statements should not take the place of detailed investigations that are required in the design of specific engineering structures and final decisions on land use.

ALLEGHENY GROUP (IPa; included in IPap)

DESCRIPTION: A highly heterogeneous unit composed of cyclic sequences of sandstone, shale, siltstone, claystone, limestone, coal, and underclay; major sandstone units are medium to coarse grained and sometimes conglomeratic; includes Vanport Limestone and commercially valuable Freeport, Kittanning, and Brookville-Clarion coals; thickness varies from 270 to 320 feet; type area is along Allegheny River in western Pennsylvania.

BEDDING: Fissile and thin bedded to massive and thick bedded depending on rock type; most major sandstone units are thick bedded; generally well developed; sandstone is frequently crossbedded.

FRACTURING: Joint formation, spacing, and density depend on rock type; more widely spaced in sandstone and closer spaced in finer grained rocks and coal; patterns are in many places regular but are locally very complex and irregular; most joints are open and subvertical; effects of faulting in some areas may be severe; subsidence fractures may be encountered in connection with underground coal and clay mining.

WEATHERING: Variable in resistance; degree and type of weathering depend on kind of rock; claystone and coal weather rapidly and more deeply than do siltstone and sandstone and, to a lesser degree, lime-

stone; mantle thicknesses are variable, but in most areas are less than 25 feet.

TOPOGRAPHY: Assortment of dendritic streams separated by irregular, rounded ridges and hills of moderate to high relief; can be rough or rolling; most sandstones form a break in the topography; areas having steep structural dips display deeper, narrower stream valleys separated by broad-topped, steep-sided divides; natural slopes are stable at moderate to fairly steep angles.

DRAINAGE: Surface drainage is generally good.

POROSITY AND PERMEABILITY: Effective porosity is generally moderate in sandstone and low in other rock types; moderate to low permeability.

GROUNDWATER: Occurrence is irregular because of wide variability of rock types; Kittanning and Freeport sandstones are major aquifers; Vanport Limestone in some areas is a good aquifer; median yield is 50 gal/min (gallons per minute); water often occurs above claystone, underclay, and coal where these impervious units prevent downward percolation and cause perching of groundwater; water may contain excessive amounts of iron; aquifers more than 100 feet below drainage level may be brackish or salty; well construction should be carefully performed in areas of oil and gas production and mined-out coal.

EASE OF EXCAVATION: Difficult in sandstone; moderately easy in weaker, fine-grained rocks; moderate drilling rate.

CUT-SLOPE STABILITY: Fair; undercutting of resistant sandstone and limestone beds by shale, claystone, underclay, and coal cause rockfalls, slumps, and landslides; homogeneous sandstone units may have good stability.

FOUNDATION STABILITY: Good; foundations on claystone and underclay should be avoided because clays tend to deform under load when wet; bedrock should be excavated to sound material; extreme caution should be taken when construction is planned over mined-out coals.

CONSTRUCTION MATERIALS: Good source of road material and fill; clay and shale are commonly used for structural clay products; some clay is suitable for refractory clay; sandstone may be suitable for building stone and embankment facing; Vanport Limestone is used for fluxstone, cement manufacture, and construction aggregate.

ROCK TEST DATA:

Butler sandstone

Unconfined compressive strength = 12,600 lb/in^2 (pounds per square inch)

Freeport sandstone

Shear strength (single shear parallel to building)
Minimum = 695 lb/in^2
Maximum = 1,695 lb/in^2
Average = 1,207 lb/in^2
Unit compressive strength
>11,550 lb/in^2
Modulus of elasticity (at 25% of ultimate strength)
Average = 1,684,000 lb/in^2
Minimum = 1,035,000 lb/in^2

Lower Kittanning interval

Shale
Compressive strength ([lb/in^2] × 1000) = 14.7
Modulus of rupture ([lb/in^2] × 1000) = 0.2

- Shale *(cont.)*
  - Impact toughness (in/in^2) = 4.4
  - Youngs modulus ([lb/in^2] × 10^6) = 2.22
  - Specific gravity = 2.72
  - Porosity (percent) = 1.7
- Siltstone
  - Compressive strength ([lb/in^2] × 1000) = 16.4
  - Modulus of rupture ([lb/in^2] × 1000) = 0.4
  - Impact toughness (in/in^2) = 3.9
  - Youngs modulus ([lb/in^2] × 10^6) = 1.03
  - Specific gravity = 2.76
  - Porosity (percent) = 1.8
- Sandstone
  - Compressive strength ([lb/in^2] × 1000) = 23.0
  - Modulus of rupture ([lb/in^2] × 1000) = 2.8
  - Impact toughness (in/in^2) = 6.6
  - Youngs modulus ([lb/in^2] × 10^6) = 3.57
  - Specific gravity = 2.70
  - Porosity (percent) = 1.4

Vanport Limestone
- Unconfined compressive strength = 3,395 lb/in^2
- Specific gravity = 2.65 to 2.72
- Absorption = 0.20 to 1.22%

Clarion Formation
- Plastic clay
  - Specimen diameter = 2.03 to 2.12 in.
  - Initial height = 3.25 to 3.44 in.
  - Initial water content = 3.3 to 4.3%
  - Dry density = 145.5 to 152.4 lb/ft^3
  - Compressive strength = 1.83 to 6.25 tons/ft^2
- Semi-flint clay
  - Specimen diameter = 0.97 in.
  - Initial height = 1.91 to 2.06 in.
  - Initial water content = 1.9 to 2.0%
  - Dry density = 166.9 to 167.7 lb/ft^3
  - Compressive strength = 7.5 tons/ft^2

REMARKS: Test data from USCE.

ALLENTOWN FORMATION (Ꞓal)

DESCRIPTION: Medium-gray dolomite and impure limestone; dark-gray chert stringers and nodules; laminated; some oolite and sharpstone conglomerate; maximum thickness is about 2,000 feet; reference sections are along Lehigh River and Jordan Creek in vicinity of Allentown, Lehigh County.

BEDDING: Well bedded; thick.

FRACTURING: Joints have a blocky pattern; well developed; moderate to highly abundant; regularly spaced, having a moderate distance between fractures; open and steeply dipping.

WEATHERING: Moderately resistant; slightly weathered to a shallow depth; decomposition results in medium-sized, blocky fragments; overlying mantle is thin in most areas; interface between bedrock and mantle is characterized by pinnacles.

TOPOGRAPHY: Undulating valley of low relief; natural slopes are gentle and stable.

DRAINAGE: Good subsurface drainage; little surface drainage.

POROSITY AND PERMEABILITY: Solution channels produce a secondary porosity of moderate to high magnitude; low permeability.

GROUNDWATER: Median yields from specific study areas range from 60 to 210 gal/min; many wells are capable of yielding 1,000 gal/min or more; aquifer can be easily contaminated; turbidity is a common water-quality problem.

EASE OF EXCAVATION: Difficult; bedrock pinnacles are a special problem; moderate to slow drilling rate; numerous sandstone beds containing chert lenses slow the drilling rate.

CUT-SLOPE STABILITY: Good; stable in vertical cuts where fractures are at a minimum.

FOUNDATION STABILITY: Good; a thorough sinkhole investigation should be undertaken.

CONSTRUCTION MATERIALS: Good source of road material, riprap, building stone, embankment facing, and fill.

ANNVILLE FORMATION (Oan; included in Oha)

DESCRIPTION: Light-gray, high-calcium limestone, mottled at base; occurs east of Susquehanna River only; maximum thickness is about 250 feet; reference section is at Millardsville quarry, eastern Lebanon County.

BEDDING: Well bedded; massive to thick bedded.

FRACTURING: Joints have a blocky pattern; moderately well developed; moderately to highly abundant; fairly regular, having a moderate distance between fractures; most fractures are open but some are filled with calcite; steeply dipping to vertical.

WEATHERING: Moderately resistant; slightly weathered to a shallow depth; medium-sized blocks commonly result; overlying mantle is moderately thick; bedrock/mantle interface is in most places pinnacled.

TOPOGRAPHY: Rolling valley of low relief; natural slopes are gentle and stable.

DRAINAGE: Good subsurface drainage; poor surface drainage; sinkholes are common.

POROSITY AND PERMEABILITY: Joint and solution openings provide a secondary porosity of moderate to high magnitude; low permeability.

GROUNDWATER: Industrial and public groundwater supplies are available; wells have encountered solution openings for very large yields; usually of excellent quality for most uses; water may be relatively hard.

EASE OF EXCAVATION: Difficult; bedrock pinnacles are a special problem; moderate drilling rate.

CUT-SLOPE STABILITY: Good; steeply dipping beds inclined toward the construction have only fair stability.

FOUNDATION STABILITY: Good; a thorough investigation should be made for possible collapse areas.

CONSTRUCTION MATERIALS: A high-calcium limestone; good source of fluxstone.

ROCK TEST DATA:
Specific gravity = 2.77 to 2.79
Absorption = 0.24 to 0.46%

REMARKS: Test data from PDT.

ANORTHOSITE (Xa, a)

DESCRIPTION: An igneous rock, medium- to coarse-grained, light- to dark-gray; contains plagioclase feldspar; reference section is near Honey Brook, Chester County.

BEDDING: None.

FRACTURING: Joints; blocky pattern; moderately developed; moderately abundant; irregular; widely spaced; open and moderately dipping.

WEATHERING: Highly resistant; slightly weathered to a shallow depth, forming smooth, rounded, large boulders; overlying mantle is thin.

TOPOGRAPHY: Hills of medium relief; natural slopes are fairly steep and stable.

DRAINAGE: Good surface drainage.

POROSITY AND PERMEABILITY: Joint openings produce a secondary porosity of low magnitude; low permeability.

GROUNDWATER: The median yield is less than 10 gal/min; yield of 25 gal/min or more might be obtained from wells properly sited and developed.

EASE OF EXCAVATION: Difficult; large surface and near-surface boulders are a special problem; slow drilling rate.

CUT-SLOPE STABILITY: Good.

FOUNDATION STABILITY: Good; should be excavated to sound material.

CONSTRUCTION MATERIALS: Good source of road material, riprap, building stone, embankment facing, and fill.

ANTES FORMATION (included in Or)

DESCRIPTION: Dull-black shale; weathers to clayey-brown color; contains graptolites; light- to medium-gray laminations of silty shale define the bedding; highly fissile; at least 50 feet thick and may reach a maximum thickness of 300 feet; reference section is directly east of McConnellsburg, Fulton County.

BEDDING: Moderately well bedded; thin to fissile.

FRACTURING: Joints are well developed and highly abundant; spacing is variable; moderate distance between fractures; open and steeply dipping.

WEATHERING: Slightly resistant; moderate to highly weathered to a moderate depth; weathers readily to clayey loam; weathers into chips and slabs about a quarter of an inch thick; weathered chips of shale are numerous in the soil; mantle is thick.

TOPOGRAPHY: Rolling valleys of medium relief; natural slopes are stable and moderate to steep along streams.

DRAINAGE: Good surface drainage.

POROSITY AND PERMEABILITY: Joints, faults, and bedding partings provide a secondary porosity of low magnitude; low permeability.

GROUNDWATER: Median yield is 15 gal/min; most favorable well sites are in upland valleys; fracture openings decrease in number and size as depth increases; the presence of some iron and hydrogen sulfide causes quality problems.

EASE OF EXCAVATION: Moderately easy; fast drilling rate.

CUT-SLOPE STABILITY: Fair, due to rapid disintegration when exposed to moisture for a relatively short time.

FOUNDATION STABILITY: Good; should be excavated to fresh bedrock.

CONSTRUCTION MATERIALS: Good source of road material and fill.

ANTIETAM FORMATION (Ꞓa; included in Ꞓah and Ꞓul)

DESCRIPTION: Light-gray, buff-weathering quartzite and quartz schist; some ferruginous quartzite; fine-grained; maximum thickness is about 300 feet; reference section is south of Columbia, Lancaster County, along the Susquehanna River.

BEDDING: Moderately well to well bedded; thick.

FRACTURING: Joint and cleavage planes display a blocky pattern; moderately well developed; moderately abundant; widely spaced and fairly regular; steeply dipping and open.

WEATHERING: Highly resistant to weathering; usually slightly to moderately weathered to a shallow depth; hackly, large, irregularly shaped fragments result from weathering; overlying mantle is thin.

TOPOGRAPHY: Hills of medium to high relief; natural slopes are steep and stable.

DRAINAGE: Good surface drainage.

POROSITY AND PERMEABILITY: Joint- and cleavage-plane openings provide a secondary porosity of low magnitude; low permeability.

GROUNDWATER: Median well yield is 20 gal/min; for maximum yield, valleys, fault zones, and other fracture zones are most favorable well sites.

EASE OF EXCAVATION: Difficult; slow drilling rate, in part due to many quartz veins that exceed 12 inches in width; large boulders may be a special problem; where highly weathered, moderately easy to excavate.

CUT-SLOPE STABILITY: Good; locally, where highly fractured and weathered, cut-slope stability is only fair.

FOUNDATION STABILITY: Good; should be excavated to sound material.

CONSTRUCTION MATERIALS: Good source of road material, riprap, building stone, and embankment facing; in some localities, a source of refractory brick, and, where intensely fractured and weathered, sand.

AXEMANN FORMATION (Oa; included in Oba)

DESCRIPTION: Light-gray limestone, fossiliferous, coarsely crystalline; interbedded with silty, fine-grained dolomitic limestone; some oolitic and conglomeratic limestone; flint concretions and chert occur throughout the unit; in certain areas, limonite has replaced oolitic limestone; maximum thickness is about 500 feet; reference section is 1 mile south of the village of Axemann, Centre County.

BEDDING: Well bedded; thick to thin.

FRACTURING: Joints have a blocky pattern; well developed; moderately abundant; regularly spaced, having a moderate distance between fractures; steeply dipping; mostly open; some are calcite filled.

WEATHERING: Moderately resistant; slightly weathered to a shallow depth; small to large blocky fragments result; overlying mantle is variable due to bedrock pinnacles; considerable chert and flint are found in the soil.

TOPOGRAPHY: Rolling valleys of low relief; gentle and stable natural slopes.

DRAINAGE: Good subsurface drainage; minor surface drainage.

POROSITY AND PERMEABILITY: Joint and solution openings provide a secondary porosity of moderate to high magnitude; moderate permeability.

GROUNDWATER: Median yield is 100 gal/min; yields of over 100 gal/min have been reported; water quality is generally good, but easily contaminated; hardness is sometimes high.

EASE OF EXCAVATION: Difficult; bedrock pinnacles are a special problem; moderate drilling rate due to presence of chert and flint.

CUT-SLOPE STABILITY: Good; steeply dipping beds inclined toward cut may require moderate to gentle slopes.

FOUNDATION STABILITY: Good; should be excavated to uniformly sound material; should be thoroughly investigated for solution openings which could lead to surface collapse.

CONSTRUCTION MATERIALS: Good source of road material and fill.

BALD EAGLE FORMATION (Obe; included in Ojb)

DESCRIPTION: Gray to reddish-gray to brownish-gray, fine- to coarse-grained, crossbedded sandstone, and quartz-pebble conglomerate (Lost Run Member); maximum thickness about 1,000 feet; reference section is in Tyrone Gap, Blair County.

BEDDING: Moderately well developed, thick beds.

FRACTURING: Joints are poorly formed in blocky pattern; slightly fractured; moderately spaced in irregular sequence; open and steeply dipping.

WEATHERING: Highly resistant; slightly weathered to shallow depth; breaks into large blocks having hackly surfaces; overlying mantle is thin.

TOPOGRAPHY: Mountain ridges and rolling to rough, steep terrain; natural slopes are stable at steep angles.

DRAINAGE: Surface drainage is good.

POROSITY AND PERMEABILITY: Effective porosity from interstitial and joint openings is low to moderate; moderately permeable.

GROUNDWATER: Median yield is 10 gal/min; in most areas, very poor topographic position for groundwater development; best well sites are in valleys and on hillslopes.

EASE OF EXCAVATION: Difficult; relative drillability is slow.

CUT-SLOPE STABILITY: Good.

FOUNDATION STABILITY: Good; should be excavated to sound material.

CONSTRUCTION MATERIALS: Good source of road material, riprap, embankment facing, and fill.

BALTIMORE GNEISS (SEE GRANITIC GNEISS AND GABBROIC GNEISS)

BEDFORD SHALE (included in MDbr, MDcr, MDsr, MDso, and MDbv)

DESCRIPTION: Hard, micaceous, light-gray to medium-dark-gray shale; interbedded siltstone; some very fine grained, light-gray sandstone; maximum thickness is about 40 feet; type section is along Tinkers Creek near Bedford, Bedford Township, Cuyahoga County, Ohio.

BEDDING: Well bedded; thin.

FRACTURING: Joints are poorly developed; irregular pattern; very small openings to shallow depth; widely spaced.

WEATHERING: Moderately resistant; moderately weathered to shallow depth; results in loose rubble of small fragments to rectangular plates; mantle is thin where not covered by glacial deposits.

TOPOGRAPHY: Valley slopes in Mercer and Venango Counties; uplands of low relief in Crawford and Erie Counties.

DRAINAGE: Good surface drainage.

POROSITY AND PERMEABILITY: Low to very low porosity and permeability; few fractures present are shallow; no effective primary porosity.

GROUNDWATER: Generally a poor aquifer; drilling deeper into shale will yield little or no additional water; reported maximum yield is 45 gal/min; water is generally hard and high in iron.

EASE OF EXCAVATION: Difficult; fast drilling rate; siltstone and sandstone interbeds may slow rate.

CUT-SLOPE STABILITY: Good to fair depending on length of time unit is exposed to weathering.

FOUNDATION STABILITY: Good; should be excavated to sound bedrock.

CONSTRUCTION MATERIALS: Good source for fill.

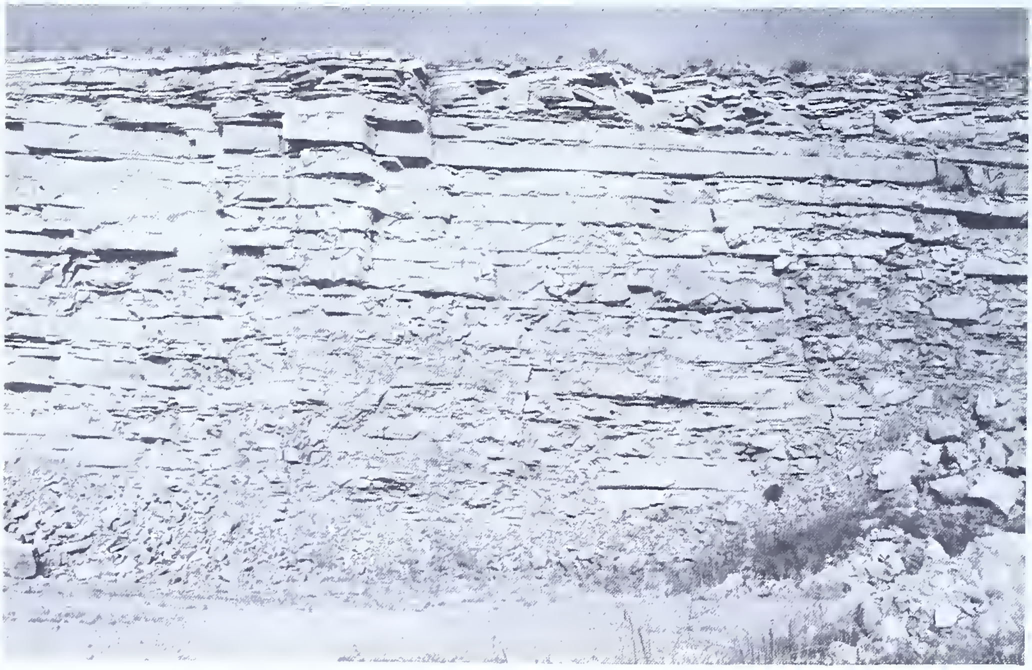
BEEKMANTOWN GROUP (Ob)

DESCRIPTION: Where these rocks have not been subdivided into separate formations, they are interbedded, finely laminated, light-gray limestone containing dark-gray dolomite beds; dolomite is fractured, and the fractures are recemented by white calcite; limestone weathers to a pale-gray surface contrasting with the yellowish-gray-weathering dolomite; maximum thickness is about 2,300 feet; reference section is between Leesport and Reading (Berks County) along the Schuylkill River.

BEDDING: Well bedded; thick.

FRACTURING: Joints have a blocky pattern; moderately to well developed; moderately abundant; regularly spaced, having a moderate distance between fractures; both a steeply dipping set and a gently dipping set are present; most are open, but some are filled with calcite.

WEATHERING: Moderately resistant; slightly weathered to a shallow depth; small to large, blocky fragments result; overlying mantle is variable in thickness, in most places greater than 5 feet; bedrock pinnacles are characteristic.



TOPOGRAPHY: Flat to rolling valleys of low relief; gentle and stable natural slopes.

DRAINAGE: Good subsurface drainage; minor surface drainage.

POROSITY AND PERMEABILITY: Joint and solution-channel openings provide a secondary porosity of low to moderate magnitude; low permeability.

GROUNDWATER: High yields from fractures and solution cavities; median yield is 50 gal/min in southeastern Pennsylvania; industrial and public supplies are available in most areas.

EASE OF EXCAVATION: Difficult; bedrock pinnacles are a special problem; moderate drilling rate; chert beds, lenses, and quartz sand slow the drilling rate.

CUT-SLOPE STABILITY: Good; intersection of joint and bedding surfaces may create a problem if the depth of cut is extreme.

FOUNDATION STABILITY: Good; should be investigated thoroughly for solution openings.

CONSTRUCTION MATERIALS: Good source of road material, riprap, building stone, embankment facing, and fill.

ROCK TEST DATA:
Specific gravity = 2.70 to 2.77
Absorption = 0.16 to 0.58%

REMARKS: Test data from PDT.

BELLEFONTE FORMATION (Obf; included in Oba)

DESCRIPTION: Light- to medium-gray, tan-weathering, very fine grained dolomite (Tea Creek Member) at top; minor sandstone beds; some chert; medium-gray, medium-crystalline dolomite (Coffee Run Member) at base; maximum thickness is about 2,100 feet; reference section is at Bellefonte, Centre County.

BEDDING: Well bedded; thick to medium bedded.

FRACTURING: Joints have a blocky pattern; moderately to well developed; moderately abundant; regularly spaced, having a moderate distance between fractures; both a steeply dipping set and a gently dipping set are present; most are open, but some are filled with calcite.

WEATHERING: Moderately resistant; slightly weathered to a shallow depth; small to large, blocky fragments result; overlying mantle is variable in thickness, in most places greater than 5 feet; bedrock pinnacles are characteristic.

TOPOGRAPHY: Flat to rolling valleys of low relief; gentle and stable natural slopes.

DRAINAGE: Good subsurface drainage; minor surface drainage.

POROSITY AND PERMEABILITY: Joint and solution-channel openings provide a secondary porosity of low to moderate magnitude; low permeability.

GROUNDWATER: Median yield of wells is 100 gal/min; industrial and public supplies are available; highest yields are from fractures and solution cavities.

EASE OF EXCAVATION: Difficult; bedrock pinnacles are a special problem; moderate drilling rate; chert beds, lenses, and quartz sand slow the drilling rate.

CUT-SLOPE STABILITY: Good; intersection of joint and bedding surfaces may create a problem if the depth of cut is extreme.

FOUNDATION STABILITY: Good; should be investigated thoroughly for solution openings.

CONSTRUCTION MATERIALS: Good source of road material, riprap, building stone, embankment facing, and fill.

BENNER FORMATION (included in Obl and Ocl)

DESCRIPTION: Light- to dark-gray, very finely crystalline limestone at top, includes a high-calcium limestone called the Valentine Member; an argillaceous limestone containing interbedded metabentonite beds (Valley View Member) is at base; laterally equivalent to impure limestones of Oak Hall Member and dark-gray limestone of Stover Member, which has dolomite streaks at base; the Benner Formation has been called the Linden Hall Formation by some geologists; maximum thickness of 180 feet in central Pennsylvania includes a maximum thickness of 90 feet for the Valentine Member; reference section is at the village of Valentine near Bellefonte, Centre County.

BEDDING: Well bedded; mostly fissile to flaggy; locally thick bedded.

FRACTURING: Joints have a blocky pattern; some have a platy pattern; moderately well developed; moderately to highly abundant; fairly regular, having a moderate distance between fractures; most fractures are open but some are filled with calcite; steeply dipping to vertical.

WEATHERING: Moderately resistant; slightly weathered to a shallow depth; shaly limestone beds appear moderately weathered to a deeper depth; medium-sized blocks commonly result; shaly units weather to small, pencil-like, flat fragments; overlying mantle is moderately thick; the bedrock-mantle interface is characterized by pinnacles in most places.

TOPOGRAPHY: Rolling valley of low relief; natural slopes are gentle and stable.

DRAINAGE: Good subsurface drainage; poor surface drainage; sinkholes are common.

POROSITY AND PERMEABILITY: Joint and solution openings provide a secondary porosity of moderate to high magnitude; low permeability.

GROUNDWATER: Median yield is 50 gal/min; excellent quality in most areas.

EASE OF EXCAVATION: Difficult, bedrock pinnacles are a special problem; moderate drilling rate.

CUT-SLOPE STABILITY: Good; steeply dipping beds inclined toward the construction have only fair stability.

FOUNDATION STABILITY: Good; should be thoroughly investigated for solution openings.

CONSTRUCTION MATERIALS: Good source of road material and fill.

ROCK TEST DATA:
Specific gravity = 2.67
Absorption = 0.50%
Valentine Member
  Specific gravity = 2.69 to 2.71
  Absorption = 0.10 to 48%

REMARKS: Test data from PDT.

BEREA SANDSTONE (included in MDbr and MDbv)

DESCRIPTION: Fine- to very fine grained, silty, micaceous, light-gray sandstone; some interbedded medium-dark-gray silty shale; some calcareous sandstone, ripple-marked; maximum thickness is about 33 feet; reference section is at the mouth of Sugar Run, West Shenango Township, Crawford County.

BEDDING: Well developed; flaggy to thin.

FRACTURING: Joints are well formed, widely spaced, few in number, open, and vertical.

WEATHERING: Moderately to slightly resistant; moderate to deep weathering; where calcareous, may be deeply weathered; mantle is thin.

TOPOGRAPHY: Gentle valley slopes and uplands; natural slopes are stable.

DRAINAGE: Surface drainage is good.

POROSITY AND PERMEABILITY: Moderate to low porosity and permeability, depending on thickness of unit and degree of cementation of sandstone.

GROUNDWATER: Estimated high yield is 60 gal/min; median yield is less than 10 gal/min; locally contains salt water; may contain gas; water is hard to very hard; iron content is often excessive.

EASE OF EXCAVATION: Moderately easy to easy where rock is loosely cemented or weathered; drilling rate is moderate to fast.

CUT-SLOPE STABILITY: Good to poor depending on amount of weathering; calcareous sandstone weathers rapidly to loose sand.

FOUNDATION STABILITY: Good; must be excavated to sound bedrock.

CONSTRUCTION MATERIALS: Good source of fill.

BLOOMSBURG FORMATION (Sb; included in Sbm, Swm, DSkm, and DSkc)

DESCRIPTION: Predominantly red shale and siltstone; some sandstone, thin, impure limestone, and green shale; maximum thickness is about 500 feet; type section is one block north of West Main Street on Railroad Avenue in Bloomsburg, Columbia County.

BEDDING: Moderately well bedded; fissile to thin; sandstone units are mostly flaggy to thick.

FRACTURING: Joints have a seamy to platy pattern; poorly formed; moderately to highly fractured; regularly spaced, having a very close distance between fractures; open and steeply dipping.

WEATHERING: Only slightly resistant to weathering; highly weathered to a moderate depth; irregularly shaped, very small fragments result; overlying mantle is thin.

TOPOGRAPHY: Rolling hills of medium relief; natural slopes are fairly steep and stable.

DRAINAGE: Good surface drainage.

POROSITY AND PERMEABILITY: Joint-, fault-, and bedding-plane openings provide a secondary porosity of low to moderate magnitude; moderate permeability.

GROUNDWATER: Median yield is 45 gal/min; hydrogen sulfide has been noted in some wells.

EASE OF EXCAVATION: Moderately easy; relatively fast drilling rate.

CUT-SLOPE STABILITY: Poor to fair, due to rapid disintegration when exposed to moisture for a relatively short time.

FOUNDATION STABILITY: Good; should be excavated to sound material.

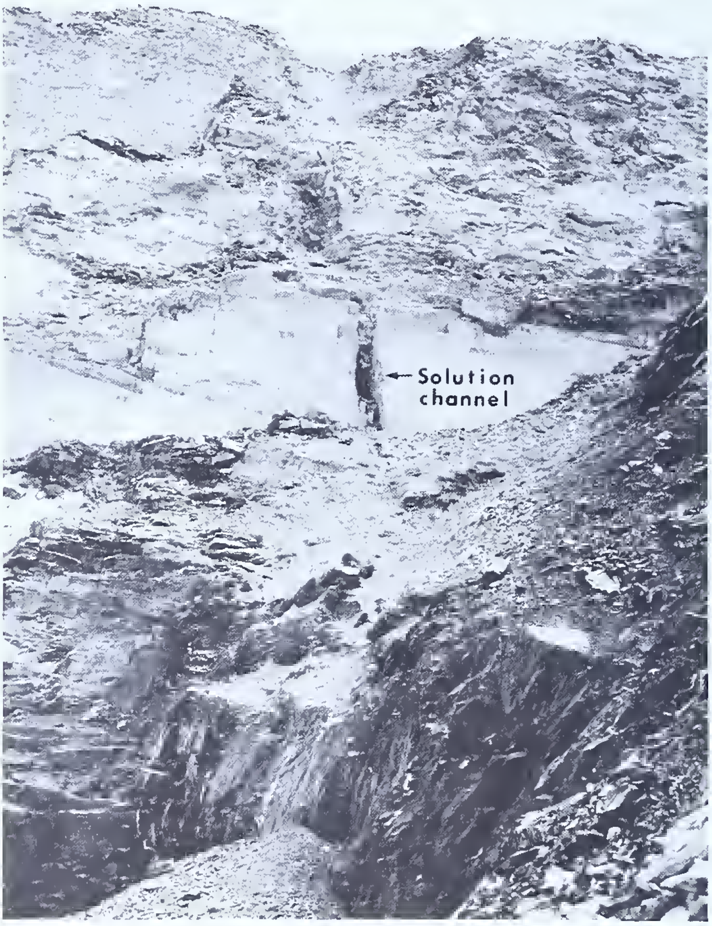
CONSTRUCTION MATERIALS: Good source of road material and fill; possible source of raw material for common brick.

ROCK TEST DATA:
Sandstone
Unconfined compressive strength = 18,930-34,200 lb/in^2
Tensile strength = 362-1,183 lb/in^2
Modulus of elasticity = 7.5 × 10^6 (50% peak strength) lb/in^2
Porosity = 0.2%
Absorption = 0.1%
Density = 169.9 lb/ft^3
Specific gravity (bulk, surface saturated, dry) = 2.72
Rebound (Smith hammer in numbers) = 37.4-40.7
Siltstone
Unconfined compressive strength = 6,510-29,140 lb/in^2
Tensile strength = 179.1-504.2 lb/in^2
Modulus of elasticity = 7.0 × 10^6 (50% peak strength) lb/in^2
Porosity = 0.9%
Absorption = 0.3%
Density = 174.2 lb/ft^3
Specific gravity = 2.79
Rebound = 0.33-37.5
Shale
Water of plasticity = 15 to 17%
Dry shrinkage = 1.0%

REMARKS: Test data on shales are from USBM; on siltstone and sandstone from USCE; specimens for strength tests were prepared from 2-1/8-inch diameter core; each specimen has a length-to-diameter ratio between 2.0 and 2.5.

BOSSARDVILLE FORMATION (included in Sdp and DSop)

DESCRIPTION: Medium- to dark-gray, very fine to fine-grained limestone; partly argillaceous, sandy and dolomitic; contains some interbedded calcareous shale and dolomite; thickness is about 100 feet; reference section is at Herbert R. Imbt quarry, Bossardsville, Monroe County.



BEDDING: Thin to laminated; few thick beds; shows distinctive, wavy, ribbon pattern in many areas; thickness is generally 2 to 4 inches or less.

FRACTURING: Joints are well developed; irregular spacing, 2 inches to 2 feet, in a blocky pattern; generally open; some are filled with calcite. Cleavage is highly developed in association with folds.

WEATHERING: Moderately resistant; weathered to a shallow depth, but deeply weathered along some narrow solution channels; minimal

sinkhole development; overlying mantle is thin to moderately thick, estimated to range from 1 to 10 feet; thinly laminated beds weather to shale-chip rubble; thicker beds weather to blocky fragments.

TOPOGRAPHY: Flank of ridge of moderate relief; moderate and stable natural slopes.

DRAINAGE: Good surface drainage; minor subsurface drainage.

POROSITY AND PERMEABILITY: Joint and bedding openings and narrow solution channels provide a moderate secondary porosity and permeability.

GROUNDWATER: Potential yield is greater than 150 gal/min; water is high in solutes and hard to very hard at 8 to 19 grains/gal.

EASE OF EXCAVATION: Moderately difficult; moderate drilling rate; scattered, near-vertical, narrow solution openings may deflect drill rods.

CUT-SLOPE STABILITY: Good; some rockfall and shale-chip rubble from freshly made rock cuts.

FOUNDATION STABILITY: Excellent; should be investigated for possible solution openings and excavated to sound bedrock; pinnacle weathering is not pronounced.

CONSTRUCTION MATERIALS: Good source of aggregate.

BRALLIER FORMATION (included in Dbh)

DESCRIPTION: Interbedded light-gray, siliceous siltstone and light-gray, hard, silty shales; contains fossiliferous lenses; maximum thickness is about 1,800 feet; reference section is in quarries at north end of Market Street, Williamsport, Lycoming County.

BEDDING: Well bedded; mostly thin, but shales may be very thick; graded beds in siltstone.

FRACTURING: Joints are highly developed and irregular; closely spaced, having narrow openings; steeply dipping.

WEATHERING: Moderately resistant; moderately weathered to a moderate depth; mantle is moderately thin; tabular fragments.

TOPOGRAPHY: Hills and ridges of moderate relief; natural slopes are fairly steep and stable.

DRAINAGE: Good surface drainage.

POROSITY AND PERMEABILITY: Joint and bedding openings provide a secondary porosity of low magnitude; low permeability.

GROUNDWATER: Aquifer potential moderate for domestic supply; reported yields are 1 to 15 gal/min.

EASE OF EXCAVATION: Easy to moderately difficult; drilling rate is fast.

CUT-SLOPE STABILITY: Fair to good; steep cuts can be maintained except in weathered shale.

FOUNDATION STABILITY: Good; should be excavated to sound material.

CONSTRUCTION MATERIALS: Good source of road material and random fill.

BRIDGETON FORMATION (included in Tpb)

DESCRIPTION: Extensively crossbedded clayey sand stained reddish brown; below the reddened zone, the sand is either yellow or white and irregularly stained reddish to orange brown; locally, beds of gravel are present; gravel is mostly vein quartz, chert, and quartzite; maximum thickness is about 30 feet; reference section is 6.2 miles due west of Bridgeton, New Jersey.

BEDDING: Well bedded; extensively crossbedded.

FRACTURING: None apparent.

WEATHERING: Deeply weathered.

TOPOGRAPHY: Upland terrace remnant at an altitude of between 90 and 150 feet above sea level; parallel to the Delaware River.

DRAINAGE: Good surface drainage; locally may be poor.

POROSITY AND PERMEABILITY: High porosity and moderate permeability.

GROUNDWATER: Gravels are main source of groundwater; generally thin and irregularly distributed; minimum of 2 gal/min; maximum reported yield of 1,200 gal/min; induced recharge is relatively important for sustained yield.

EASE OF EXCAVATION: Easy.

CUT-SLOPE STABILITY: Good to poor; maintains steep slope for short period of time; weathers rapidly.

FOUNDATION STABILITY: May be good; special work such as replacement, compaction, and preparation of drainage facilities may be necessary.

CONSTRUCTION MATERIALS: Good source of sand.

BRUNSWICK FORMATION (Trb)

DESCRIPTION: Typically reddish-brown shale, mudstone, and siltstone; beds of green shale and brown shale occur; very fine grained; near base, rock is tough, red argillite interbedded in some places with dark-gray argillite; maximum thickness is about 6,000 feet; reference section is along the Delaware River between Kintnersville and Erwinna, Bucks County.

BEDDING: Moderately well bedded; thin to flaggy.

FRACTURING: Joints have blocky pattern; moderately developed; moderately abundant; closely spaced; steeply dipping; mostly open; some are filled with quartz and calcite.

WEATHERING: Moderately resistant; moderately weathered to a moderate depth; weathered fragments range in size from elongated and pencil-like to medium-sized, irregularly shaped blocks; smaller fragments result from rapid hydration of minerals in exposed outcrop; overlying mantle is moderately thick.

TOPOGRAPHY: Undulating hills of low relief; natural slopes are moderately steep and stable.

DRAINAGE: Good surface drainage.

POROSITY AND PERMEABILITY: Joint and bedding planes provide secondary porosity of moderate magnitude; moderate permeability.

GROUNDWATER: Average yield is 60 gal/min; highest yields are obtained from wells ranging in depth from 200 to 550 feet; wells less than

2,000 feet apart generally show some interference; lithology is an important factor in well yields; sandstone and conglomerate show highest yields.

EASE OF EXCAVATION: Weathered zone is moderately easy; unweathered rock is difficult; moderate to fast drilling rate is expected, except adjacent to diabase, where rock is harder and drilling rate is slow.

CUT-SLOPE STABILITY: Fair to poor; landslides occur where cut slopes are steep and rocks dip toward cut.

FOUNDATION STABILITY: Good; should be excavated to sound material; good drainage is necessary.

CONSTRUCTION MATERIALS: Good to fair source of road material and fill; part of formation is good source of raw material for common brick and lightweight aggregate.

ROCK TEST DATA:
Water of plasticity = 18 to 19%
Drying shrinkage = 1 to 5%

REMARKS: Test data from USBM.

BRYN MAWR FORMATION (Tbm)

DESCRIPTION: White, yellow, and brown gravel and sand; reddish brown locally; some silt; maximum thickness reported is 20 feet; reference section is at Bryn Mawr, Montgomery County.

BEDDING: Moderately bedded.

FRACTURING: None apparent.

WEATHERING: Deeply weathered.

TOPOGRAPHY: Isolated remnants capping hills; occurs at elevations higher than 180 feet above sea level.

DRAINAGE: Good surface drainage.

POROSITY AND PERMEABILITY: Moderate to high porosity and permeability.

GROUNDWATER: Rock unit is too thin to be an important aquifer; yields in excess of 50 gal/min may be obtained from very shallow drilled wells or dug wells.

EASE OF EXCAVATION: Easy; fast drilling rate.

CUT-SLOPE STABILITY: Poor.

FOUNDATION STABILITY: Poor; some replacement, compaction, and drainage facilities may be necessary.

CONSTRUCTION MATERIALS: Good source of sand and gravel.

BUFFALO SPRINGS FORMATION (€bs; included in €sb)

DESCRIPTION: Light-gray to pinkish-gray, fine to coarsely crystalline limestone and interbedded dolomite; sandy beds are found locally; maximum thickness is about 1,000 feet; reference section is 0.7 mile southeast of the village of Buffalo Springs, Lebanon County.

BEDDING: Well bedded; generally thick; flaggy and massive in some places.

FRACTURING: Joint pattern is irregular and moderately developed; joints are moderately abundant and irregularly spaced, having wide to moderate distance between fractures; most are open but some are filled with quartz and calcite; steeply dipping.

WEATHERING: Moderately resistant; moderately weathered to a shallow depth; small, flat fragments ranging to large boulders result; the overlying mantle is thin to moderately thick; bedrock-mantle interface is characterized by pinnacles.

TOPOGRAPHY: Rolling valleys of low relief; natural slopes are gentle and stable.

DRAINAGE: Good subsurface drainage; little surface drainage.

POROSITY AND PERMEABILITY: Solution channels provide a secondary porosity of moderate magnitude; low permeability.

GROUNDWATER: In the Lebanon Valley, the median yield of wells is 160 gal/min; in the Lancaster Valley, however, the median yield is 10 gal/min.

EASE OF EXCAVATION: Difficult; bedrock pinnacles are a special problem; moderate drilling rate; locally, sandstone beds slow the drilling rate.

CUT-SLOPE STABILITY: Good.

FOUNDATION STABILITY: Good; thorough investigation for sinkholes and irregular bedrock surface should be undertaken.

CONSTRUCTION MATERIALS: Good source of road material, riprap, and fill.

ROCK TEST DATA:
Specific gravity = 2.77
Absorption = 0.48%

REMARKS: Test data from PDT.

BURGOON SANDSTONE (Mb; included in Mbc)

DESCRIPTION: Medium-gray to light-gray, medium-grained, cross-bedded sandstone, weathering to buff or light brown; locally has medium- to small-pebble conglomerate near base; contains a few thin, very dark gray, silty shale beds and some very thin, coaly horizons; maximum thickness is about 300 feet; type section is at Burgoon Run, Blair County.

BEDDING: Well developed; medium and thick beds.

FRACTURING: Joints form a recognizable blocky pattern; some joints are irregular and slightly curved; most joints are nearly vertical and moderately to widely spaced; very narrow to moderately narrow joint openings.

WEATHERING: Generally highly resistant; moderately weathered to shallow depth; natural fragmentation is slabby, rubbly, and blocky, locally flaggy; overlying mantle is thin.

TOPOGRAPHY: Forms steep slopes and cliffs along valley sides; very gently rolling upland topography reflecting near-horizontal to very gently dipping beds; steep valley sides covered with slabby to blocky sandstone fragments.

DRAINAGE: Very good surface drainage.

POROSITY AND PERMEABILITY: Primary porosity is low to moderate, but secondary porosity (joint and bedding openings) is high; overall a high total effective porosity; generally high permeability.

GROUNDWATER: Frequently an excellent aquifer; artesian flow to be expected in some cases, and yields of over 300 gal/min are possible; best well sites are away from anticlinal axes, along flanks of folds having extensive Burgoon outcrops; salt water may be encountered in very deep wells drilled near synclinal axes; iron content of water may also increase with depth.

EASE OF EXCAVATION: Difficult; slow relative drillability.

CUT-SLOPE STABILITY: Good; some dip-slip movement is possible where interbedded shales are undercut.

FOUNDATION STABILITY: Good.

CONSTRUCTION MATERIALS: Good source of material for riprap, crushed sandstone aggregate, heavy embankment facing, and fill.

BUTTERMILK FALLS LIMESTONE (included in Dbe)

DESCRIPTION: Medium-gray, fine- to coarsely crystalline, fossiliferous, partly argillaceous limestone, gray, calcareous, silty shale, and dark-gray chert; deeply leached in western part of outcrop belt; maximum thickness is 270 feet, thinning westward to 40 feet; reference section is in abandoned quarry near East Stroudsburg, Monroe County, near intersection of Interstate Route 80 and U. S. Route 209 north, off dirt road to right near Holiday Inn on left, under Interstate Route 80.

BEDDING: Irregularly to evenly bedded; generally thin to medium, 1 inch to 2 feet thick; some lenticular limestone and nodular chert beds.

FRACTURING: Joints and cleavage are highly developed; irregular spacing from less than 1 inch to 1 foot; steep to gently dipping, having narrow to moderately narrow openings.

WEATHERING: Moderately resistant; moderately weathered to a shallow depth, except deeply leached and highly weathered to the west beyond glacial border.

TOPOGRAPHY: Forms fairly steep ridge flank of moderate relief in the east and more gentle ridge flank of low relief in the west.

DRAINAGE: Good surface drainage.

POROSITY AND PERMEABILITY: Joint-, cleavage-, and bedding-plane openings provide a moderate secondary porosity and permeability, except in western part of outcrop belt, where porosity and permeability are low.

GROUNDWATER: Aquifer potential is moderate to high in unweathered rock; reported yields range from 10 to 200 gal/min; hardness averages 10 gpg and specific conductance averages 450 micromhos at 25 °C.

EASE OF EXCAVATION: Moderately difficult in the east to easy in the west; drilling rate is moderate to fast.

CUT-SLOPE STABILITY: Good to poor; steep cuts can be maintained except in deeply leached bedrock.

FOUNDATION STABILITY: Generally good, but only fair where bedrock is deeply weathered; should be excavated to sound material.

CONSTRUCTION MATERIALS: Fresh bedrock provides good source of rock fill, embankment facing, and road material.

CAPE MAY FORMATION (SEE TRENTON GRAVEL)

CARDIFF CONGLOMERATE (included in Xpb)

DESCRIPTION: Alternating layers of conglomerate and quartzite; light-gray to white quartz pebbles up to 1 inch in diameter; approximately 200 feet thick; reference section is along railroad tracks north of Peach Bottom, Lancaster County.

BEDDING: Well bedded; massive.

FRACTURING: Poor cleavage parallel to bedding; joints are locally closely spaced, abundant, moderately dipping, and open.

WEATHERING: Moderately to highly resistant; slightly weathered to a shallow depth; plates and blocks result; mantle is thin.

TOPOGRAPHY: Dissected upland having gentle divides and steep-walled ravines.

DRAINAGE: Good surface drainage.

POROSITY AND PERMEABILITY: Fracture openings provide a low secondary porosity and low permeability.

GROUNDWATER: Median yield is 20 gal/min; static water levels show strong seasonal influence; water is soft and of good quality in most areas.

EASE OF EXCAVATION: Difficult; slow drilling rate.

CUT-SLOPE STABILITY: Good.

FOUNDATION STABILITY: Good.

CONSTRUCTION MATERIALS: Good source of fill.

CASSELMAN FORMATION (ℙcc; included in ℙc)

DESCRIPTION: Heterogeneous unit composed predominantly of alternating layers of shale, siltstone, and sandstone; sandstone generally is shaly and fine to medium grained; includes several freshwater limestone layers along with claystone (including underclay), and several thin, nonpersistent coals; minor red beds are found in lower part; thickness varies from 236 feet in western Washington County to about 525 feet in Somerset County; type area is along Casselman River valley in Berlin syncline, Somerset County.

BEDDING: Generally well bedded; thickness of beds varies with lithology, ranging from a fraction of an inch to several feet; sandstone is thick bedded, locally massive; shale is thin and fissile; limestone varies from well bedded to nodular; very poor bedding in claystone.

FRACTURING: Joints are poorly to moderately well formed; moderate distribution; closely to moderately spaced; open and vertical.

WEATHERING: Sandstone, siltstone, and limestone are moderately resistant; claystone, shale, and coal weather extensively and deeply; disintegration forms rubble consisting of very small plates and small, irregular blocks; overlying mantle is thin.

TOPOGRAPHY: Rolling to narrow ridges and hills of medium relief; areas having steeper structural dips display deeper, narrower stream valleys separated by broad-topped, steep-sided divides; more resistant sandstone at base has noticeable effect on relief and direction of topographic features; moderate to steep natural slopes are stable, except where red beds occur.

DRAINAGE: Surface drainage is good.

POROSITY AND PERMEABILITY: Primary porosity of sandstone is low to high; other rock types produce water through secondary porosity caused by jointing.

GROUNDWATER: Yields are highly variable depending on local effective porosity; higher yields are expected from sandstone; mining operations may disrupt normal groundwater occurrence; care should be exercised in well construction to prevent contamination of groundwater supplies in mined-out areas and in oil and gas producing areas; water is of fair quality.

EASE OF EXCAVATION: Heavily weathered coal, shale, and claystone may be excavated easily; drilling rate is fast to moderate.

CUT-SLOPE STABILITY: Good to fair; disintegration of claystone and shale under resistant sandstone and siltstone beds results in rockfalls, slumps, and landslides; cuts in thick-bedded to massive sandstone can be nearly vertical.

FOUNDATION STABILITY: Fair to good; should be excavated to sound material; heavy structures should not be located on or near claystone because of tendency to deform under load when wet.

CONSTRUCTION MATERIALS: Good source of road material and fill; claystone may provide refractory material; sandstone provides building stone and embankment facing if not platy and thin bedded.

ROCK TEST DATA:
Upper Clarksburg shale
Unconfined compressive strength = 3,674 lb/in^2

REMARKS: Test data from USCE.

CATSKILL FORMATION (Dck)

DESCRIPTION: Complex unit consisting of shale, siltstone, sandstone, and conglomerate; thickness of exposed rocks decreases to west; relative amount of red beds decreases to almost zero in northwestern Pennsylvania.

BEDDING: Well developed in most places; thicknesses range from less than 1 foot to 10 to 16 feet in coarser beds; crossbedding is common; sedimentary features are common.

FRACTURING: Well developed; closely spaced and regular in shale and siltstone; forms a blocky or platy pattern in most places; open and steeply dipping or vertical.

WEATHERING: Shale disintegrates rapidly when exposed to moisture, weathering to small, platy, triangular fragments; sandstone, siltstone, and conglomerate are moderately resistant and break up into medium and large blocks; mantle is thick in glaciated areas of northern Pennsylvania, and variable in thickness elsewhere.

TOPOGRAPHY: Plateaus of medium relief; natural slopes are stable at fairly steep angles.

DRAINAGE: Surface drainage is moderate to good; in glaciated regions, drainage is poor.

POROSITY AND PERMEABILITY: Interstitial porosity is low in coarser rocks; joints create a secondary porosity of moderate magnitude; low to moderate permeability.

GROUNDWATER: Yields in excess of 300 gal/min have been reported; water quality is good to excellent.

EASE OF EXCAVATION: Difficult; relative drillability is moderate.

FOUNDATION STABILITY: Good; shale and siltstone should be kept water free; must be excavated to sound bedrock.

CUT-SLOPE STABILITY: Good; steep cuts can be maintained in sandstone and conglomerate; siltstone and shale disintegrate rapidly; undercutting of resistant coarser beds can cause poor-quality slopes and result in rockfalls; drainage maintenance is required.

CONSTRUCTION MATERIALS: Good source of flagstone and brick raw material, aggregate, roof granules, and fill.

ROCK TEST DATA:
Permeability = 0.2 ft/day in solid rock and 5.0 ft/day in weathered rock.
Red shale
  Compression (unit load at failure) = 2,203 to 2,859 lb/in^2
  Field water content = 0.8 to 1.5%
  Unit dry weight = 169.6 lb/ft^3
Red siltstone
  Compression (unit load at failure) = 5,041 lb/in^2
  Field water content = 0.8%
  Unit dry weight = 169 lb/ft^3
  Modulus of rupture = 63 lb/in^2
Gray-brown sandstone (fine-grained; few shale chips)
  Compression (unit load at failure) = 9,728 lb/in^2
  Field water content = 0.4%
  Unit dry weight = 166.5 lb/ft^3
  Modulus of rupture = 3,308 lb/in^2

REMARKS: Test data from USCE.

CATSKILL FORMATION, BEAVERDAM RUN MEMBER (Dcbr)

DESCRIPTION: Light-olive-gray, very fine to fine-grained sandstone and siltstone; thickness is 900 to less than 100 feet; reference section is

1.1 miles north of center of Lehighton Borough on west side of U. S. Route 209, Carbon County.

BEDDING: Moderately well bedded; 0.1 inch to 1 foot thick with interspersed massive beds; massive and fissile beds alternate.

FRACTURING: Massive beds have a well-developed, blocky and slabby, closely spaced fracture pattern; fissile beds have a highly developed fracture pattern, breaking along closely spaced bedding planes and fracture surfaces into shaly fragments.

WEATHERING: Moderately resistant; bedrock is moderately weathered to a shallow depth and has a soil cover up to 15 feet thick; weathered surfaces are rough, yielding small to medium, blocky and slabby fragments and shaly rubble.

TOPOGRAPHY: Ridges of medium relief; natural slopes are moderately steep and stable.

DRAINAGE: Good surface drainage.

POROSITY AND PERMEABILITY: Joint-, fault-, and bedding-plane openings provide a moderate secondary porosity; permeability is moderate.

GROUNDWATER: Good aquifer potential and good water quality; reported yields of 30 gal/min from some wells; upland stream valleys provide most favorable locations for well siting; fracture openings and bedding-plane partings narrow at increasing depth; most wells receive greatest yield at about 200 feet or less.

EASE OF EXCAVATION: Moderately difficult in massive beds; easier in fissile, shaly beds; drilling rates are moderate, becoming faster in fissile beds; shallow excavation by ripper in bedrock is feasible, dependent upon structural attitude of beds.

CUT-SLOPE STABILITY: Good; minor rockfall and accumulation of shaly rubble at toe of cut; steeply dipping cuts are feasible where structural attitude of beds is favorable.

FOUNDATION STABILITY: Good after excavation of weathered, unconsolidated material.

CONSTRUCTION MATERIALS: Good source of rock fill or random fill depending upon variations in lithology; has been used for roofing granules.

CATSKILL FORMATION, BERRY RUN MEMBER (included in Dcbs)

DESCRIPTION: Greenish-gray to gray, fine- to coarse-grained, crossbedded sandstone with red siltstone up to 40 feet thick at top and minor amounts of shale and conglomerate; thickness is approximately 980 feet; reference section is located 1.9 miles north of center of Lehighton Borough on west side of U. S. Route 209, Carbon County.

BEDDING: Well bedded; massive and flaggy, parallel-laminated sandstones; crossbeds are common in massive portions of unit.

FRACTURING: Joints have a highly developed, irregular, blocky pattern; closely to moderately spaced; open and steeply dipping; some conchoidal surfaces.

WEATHERING: Moderately resistant; shallow to moderate depth to bedrock; weathered surface is rough, yielding blocky and flaggy fragments; moderately thick mantle.

TOPOGRAPHY: Underlies ridges and ridge flanks of moderate relief; natural slopes are moderately steep and stable; till overlies much of the outcrop area.

DRAINAGE: Good surface drainage.

POROSITY AND PERMEABILITY: Moderate to low secondary porosity in joint and bedding-plane openings; moderate permeability except in thick-bedded conglomerate, which has low permeability.

GROUNDWATER: Moderate aquifer potential; yields to 30 gal/min have been reported; best expected yields are from flaggy sandstone and siltstone; poorest yields are from shale and conglomerate.

EASE OF EXCAVATION: Moderately difficult; difficult in conglomerate; moderate drilling rate; slow rate in conglomerate.

CUT-SLOPE STABILITY: Fair to good; subject to rockfall from steep cuts due to flaggy fragments and blocks breaking away along joint- and bedding-plane openings.

FOUNDATION STABILITY: Excellent; should be excavated to sound material.

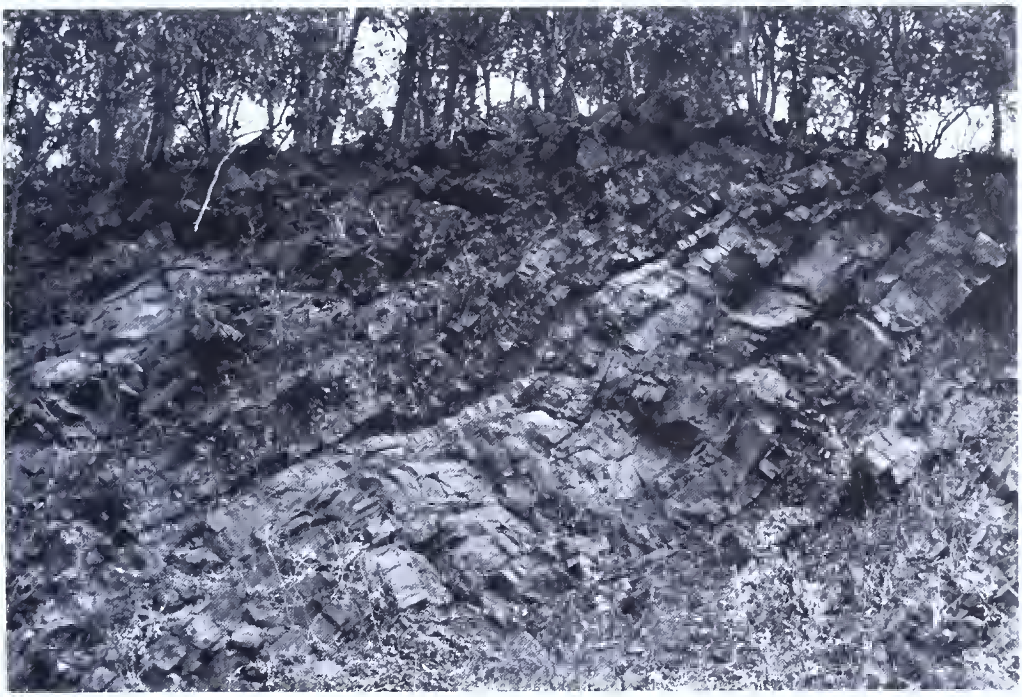
CONSTRUCTION MATERIALS: Some portions are a source of crushed aggregate, riprap, and base course; limited potential for flagstone.

CATSKILL FORMATION, BUDDYS RUN MEMBER (Dcb)

DESCRIPTION: Grayish-red to brownish-red shale, siltstone, and fine-grained sandstone with gray sandstone interbeds; thickness is 3,920 feet; reference section is on east side of Juniata River on William Penn Highway, beginning 2,000 feet north of Pa. Route 34 bridge at Newport, Perry County.

BEDDING: Well bedded; thin to medium; some crossbedded sandstone; characteristically thin bedded and platy in upper portion.

FRACTURING: Joints form blocky and shale-chip pattern; highly developed, uneven pattern; closely spaced, open, narrow, and steeply dipping to shallow.



WEATHERING: Moderately weathered to a shallow depth except on flanks of ridges in boulder colluvium, where weathering is deep; weathered surface is rough to hackly, yielding blocky and shaly fragments 2 inches to 2 feet in diameter.

TOPOGRAPHY: Underlies ridges of moderate to high relief; natural slopes are fairly steep and stable.

DRAINAGE: Good surface drainage.

POROSITY AND PERMEABILITY: Joint- and bedding-plane openings provide moderate secondary porosity in sandstone and low porosity in shale; moderate permeability in sandstone, low in shale.

GROUNDWATER: Moderate aquifer potential; expected yields of 10 to 12 gal/min from wells 100 to 250 feet deep in sandstone and siltstone; water quality is generally good, but some areas show high hardness and dissolved solids.

EASE OF EXCAVATION: Moderately difficult; easy in shale; drilling rate moderate; fast in shale.

CUT-SLOPE STABILITY: Stable to moderately stable in steep cuts; some rockfall from sandstone and siltstone and debris sliding in shale where steeply dipping; colluvium is unstable when disturbed.

FOUNDATION STABILITY: Excellent after removal of loose surface material and weathered bedrock.

CONSTRUCTION MATERIALS: Siltstone has produced crushed stone for light-duty road surfacing; sandstone has provided building stone; entire unit is good source of random and rock fill.

CATSKILL FORMATION, CLARKS FERRY MEMBER (Dccf)

DESCRIPTION: Grayish-purple and light-gray to olive-gray, medium- to coarse-grained, micaceous, conglomeratic sandstone and conglomerate with thin interbeds of dark-gray shaly claystone; thickness is 140 to 225 feet; reference section is 0.7 mile southwest of south end of old Clarks Ferry Bridge on east side of U. S. Route 22–322, Dauphin County.

BEDDING: Well bedded and crossbedded; medium to thick, 6 inches to 4 feet.

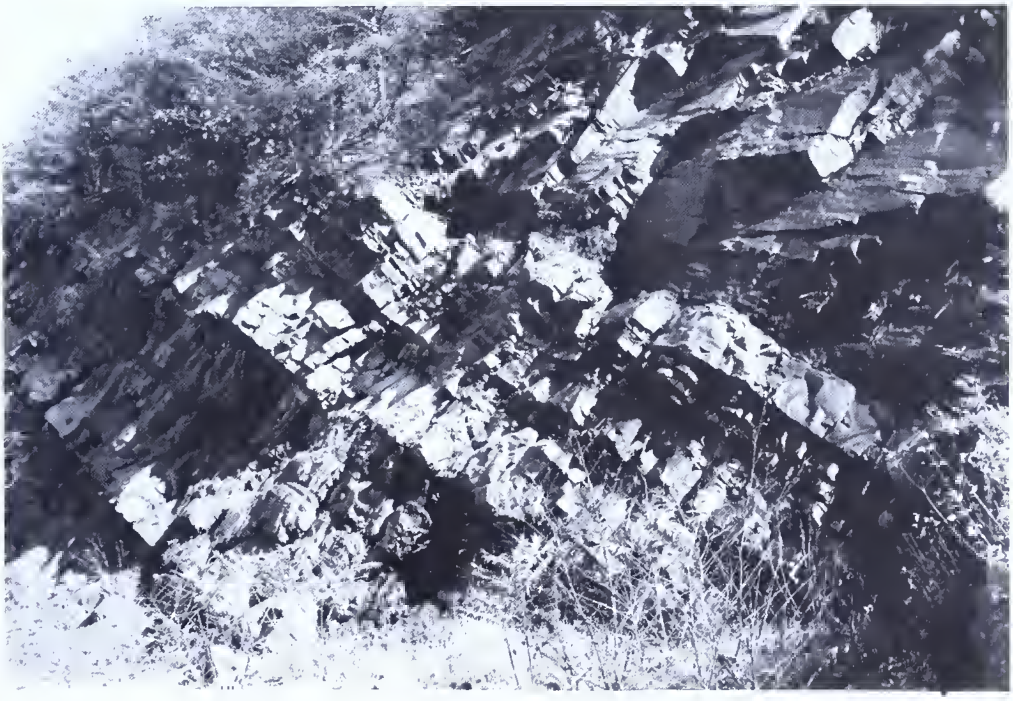
FRACTURING: Joints have a blocky pattern; highly developed, having irregular spacing, less than 2 inches to 3 feet; open in surface exposure and steeply dipping.

WEATHERING: Moderately weathered to a shallow depth, except in shaly claystone, which is more deeply weathered; weathered surface is rough, yielding blocky and tabular fragments; chippy fragments weather from shaly claystone; overlying mantle is thin to moderately thick.

TOPOGRAPHY: Underlies a distinct ridge of moderate relief or forms a bench along the flanks of higher ridges; shows no expression along some hillsides.

DRAINAGE: Good surface drainage.

POROSITY AND PERMEABILITY: Moderate secondary porosity in joint- and bedding-plane openings, except in shaly claystone, which has low secondary porosity; moderate permeability.



GROUNDWATER: Low to moderate aquifer potential; low yields are expected where the formation has topographic expression as ridges and hillside benches; moderate yields are expected where the formation has no topographic expression along ridge flanks; expected yields may reach 20 gal/min in wells about 200 feet deep; iron content may be high.

EASE OF EXCAVATION: Moderately difficult; easier in shaly claystone interbeds; moderate drilling rate; faster in shaly claystone.

CUT-SLOPE STABILITY: Good; some blocky rockfall and accumulation of shaly rubble at toe of slope; weathered shale leaves some overhanging sandstone beds above, which contribute to rockfall.

FOUNDATION STABILITY: Excellent support after removal of loose overlying mantle; areas of steep slope require special design.

CONSTRUCTION MATERIALS: Good source of random and rock fill and rock protection; sandstone has been used for decorative building stone.

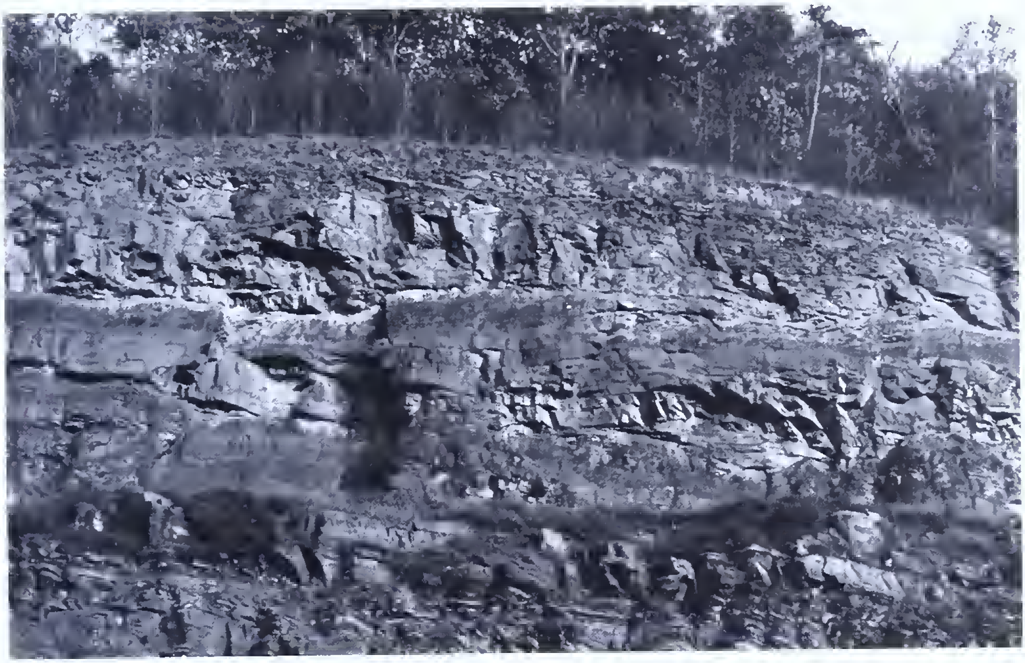
CATSKILL FORMATION, DUNCANNON MEMBER (Dcd)

DESCRIPTION: Interbedded red and gray sandstone, red siltstone, and red mudstone; sandstone is fine and very fine grained, silty, poorly sorted, micaceous, and locally conglomeratic; thickness is 560 to 3,000 feet; reference section is along east side of U. S. Route 22–322, 3.4 miles south of center of Millerstown at Buffalo-Berry Mountain highway cut, Perry County.

BEDDING: Well bedded; medium to massive; crossbedded; mudstone is thick to massive bedded.

FRACTURING: Joints are well developed in blocky and tabular pattern; generally closely spaced (2 inches to 2 feet), except widely spaced in mudstone; open, narrow, and steeply inclined to bedding.

WEATHERING: Slightly weathered to a shallow depth; weathered surface is hackly, except on mudstone, where it is smooth; fragments are blocky, 2 inches to 4 feet in diameter; overlying mantle is moderately thick, often made up of boulder colluvium from Pottsville Formation above.



TOPOGRAPHY: Hills and ridges of moderate to high relief and lower slopes of mountains capped by Pocono Formation; moderate to very steep natural slopes on which overlying mantle can be subject to landslides.

DRAINAGE: Good surface drainage.

POROSITY AND PERMEABILITY: Joint- and bedding-plane openings provide moderate secondary porosity; low in massive mudstone; moderate permeability except in mudstone, which has low permeability.

GROUNDWATER: Moderate to good aquifer potential; best yields are expected from sandstone; reported yields are 7 to 40 gal/min in wells averaging 150 feet deep; quality is generally good, except for occasional high sulfur content.

EASE OF EXCAVATION: Moderately difficult; moderate drilling rate, except in conglomerate zones, which have slower drilling rate.

CUT-SLOPE STABILITY: Fair to good; mantle and weathered bedrock are subject to landslides; unweathered rock stands well in near vertical cuts; some rockfall.

FOUNDATION STABILITY: Excellent after excavation of overlying mantle.

CONSTRUCTION MATERIALS: Good for rock fill and riprap.

CATSKILL FORMATION, IRISH VALLEY MEMBER (Dciv)

DESCRIPTION: Alternating beds of olive-gray sandstone, siltstone, and shale with red siltstone, mudstone, and shale; olive-gray sandstone commonly contains fossils; approximate maximum thickness is 250 feet; reference section is along the east bank of Larrys Creek, 0.5 mile north of U. S. Route 220 in Lycoming County.

BEDDING: Siltstone is thin to very thin bedded; shale is very thin to medium bedded; mudstone and sandstone are medium to very thick bedded.

FRACTURING: Joints are mostly well developed; highly abundant, having close spacing; steeply dipping and open.

WEATHERING: Slightly to moderately resistant; deeply weathered; fragments are blocky to pencil shaped; rough surface; mantle is moderate to thick.

TOPOGRAPHY: Forms hills and ridges of moderate relief; fairly steep to steep natural slopes; stable.

DRAINAGE: Good surface drainage.

POROSITY AND PERMEABILITY: Joint- and bedding-plane openings provide a secondary porosity of low magnitude; low permeability.

GROUNDWATER: Range of reported yields is 2 to 380 gal/min; median is 35 gal/min; water quality problems include salty water and hydrogen sulfide.

EASE OF EXCAVATION: Moderately easy; deeply weathered shale and siltstone are easily excavated; sandstone and mudstone are broken by fractures.

CUT-SLOPE STABILITY: Poor to fair due to rapid disintegration of shale and siltstone and fractured sandstone and mudstone.

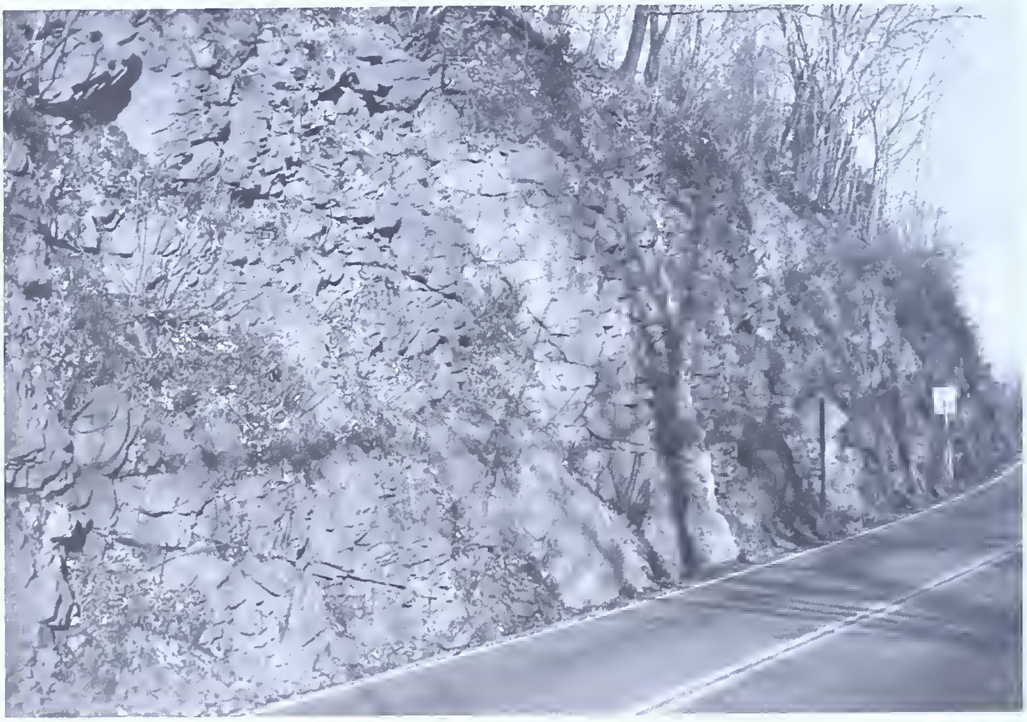
FOUNDATION STABILITY: Good; should be excavated to sound bedrock.

CONSTRUCTION MATERIALS: Good source of road material and random fill.

CATSKILL FORMATION, LONG RUN MEMBER (Dclr; included in Dclw)

DESCRIPTION: Gray, greenish-gray, and some grayish-red, crossbedded sandstone alternating with grayish-red to greenish-gray siltstone and shale; approximate thickness is 3,175 feet; reference section is along Interstate Route 80 about 1.5 miles west of Bartonsville, Monroe County.

BEDDING: Well bedded; sandstone is thick to slabby, sometimes flaggy; siltstone and shale are hackly and rubbly.



FRACTURING: Joints are well developed, closely spaced, abundant, and open.

WEATHERING: Moderately resistant; moderately weathered to a moderate depth; natural fragmentation is blocky, slabby, and, in some places, flaggy; shale and siltstone are rubbly to chippy; mantle is moderately thick.

TOPOGRAPHY: Forms terrain of only moderate relief, with elongate hills supported by sandstone; modified by glaciation and associated erosion.

DRAINAGE: Good surface drainage; angular drainage pattern has been altered to a complex pattern by glaciation.

POROSITY AND PERMEABILITY: Primary porosity in sandstone; joint- and bedding-plane openings provide a secondary porosity of low to moderate magnitude; low to moderate permeability.

GROUNDWATER: Yields range from 3 to over 100 gal/min, and the median is 20 gal/min; water is soft but potentially corrosive.

EASE OF EXCAVATION: Difficult in sandstone; moderately difficult in siltstone and shale; drilling rate is fast to moderate depending on amount of sandstone.

CUT-SLOPE STABILITY: Good in sandstone and siltstone; shale disintegrates rapidly and has only fair stability.

FOUNDATION STABILITY: Good; should be excavated to sound bedrock.

CONSTRUCTION MATERIALS: Sandstone is good local source of flagstone; good for random fill.

CATSKILL FORMATION, PACKERTON MEMBER (Dcp; included in Dcpp)

DESCRIPTION: Medium-gray, greenish-gray, and brownish-gray sandstone and conglomerate, often having reddish tinge; fine- to very coarse grained pebble conglomerate; maximum thickness is about 500 feet; reference section is in roadcut along Pa. Route 115 at base of Pocono Plateau escarpment, Monroe County.

BEDDING: Well bedded; medium to very thick; crossbedded.

FRACTURING: Joints and fracture cleavage are well developed; widely spaced; horizontal and vertical joint sets; open.

WEATHERING: Highly resistant; slight weathering to shallow depth; fragmentation is slabby to blocky; weathered rock is pale reddish purple in most places; mantle is moderately thick.

TOPOGRAPHY: Forms cliffs and steep slopes at front edge of Pocono Plateau escarpment; slopes are covered with blocky talus and boulder colluvium that are stable unless disturbed.

DRAINAGE: Good surface drainage.

POROSITY AND PERMEABILITY: Joint- and bedding-plane openings provide a secondary porosity of moderate to low magnitude; low permeability.

GROUNDWATER: Generally a poor aquifer; yields of less than 10 gal/min have been reported; may be due to adverse topographic position.

EASE OF EXCAVATION: Difficult; moderate to slow drilling rate.

CUT-SLOPE STABILITY: Generally good; where joint and bedding planes closely intersect, stability is only fair and rockfalls are common.

FOUNDATION STABILITY: Excellent; natural steep slope may be a limiting factor; on steep slopes, surficial cover must be removed.

CONSTRUCTION MATERIALS: Good source of random fill.

CATSKILL FORMATION, POPLAR GAP MEMBER (Dcpg; included in Dcpp)

DESCRIPTION: Medium-gray and light-olive-gray, fine- to coarse-grained sandstone and conglomerate having interbedded pale-red and grayish-red siltstone and shale; some pebble conglomerate; cross-bedded; about 850 feet thick; reference section is along Pa. Route 115 at the village of Poplar Gap, Monroe County.

BEDDING: Well bedded; sandstone and conglomerate are thick to very thick bedded; shale and siltstone are medium to thick.

FRACTURING: Joints and cleavage are well developed in thick-bedded rocks; joints are widely spaced; cleavage is much more closely spaced; fractures are open.

WEATHERING: Highly resistant; moderately weathered to shallow depth; natural fragments of sandstone and conglomerate are blocky and slabby; fragments of siltstone and shale are platy, chippy, and hackly; weathers to olive and yellowish gray; overlying mantle may be thick.

TOPOGRAPHY: Forms moderate hills and some low, discontinuous cliffs northwest of Pocono Plateau escarpment.

DRAINAGE: Good surface drainage.

POROSITY AND PERMEABILITY: Joint-, cleavage-, and bedding-plane openings provide a secondary porosity; sandstone and conglomerate have a fair primary porosity; total effective porosity may be high; highly permeable.

GROUNDWATER: Potential yield is greater than 300 gal/min; median is 70 gal/min; soft to moderately hard, and potentially corrosive; excessive concentrations of iron and manganese occur locally.

EASE OF EXCAVATION: Difficult; red shale may be moderately easy; moderate to slow drilling rate.

CUT-SLOPE STABILITY: Good in sandstone and conglomerate; where joints, cleavage, and bedding closely intersect, stability is only fair and rockfalls are common.

FOUNDATION STABILITY: Good; should be excavated to sound bedrock.

CONSTRUCTION MATERIALS: Potential source of flagstone, riprap, and fill.

CATSKILL FORMATION, SAWMILL RUN MEMBER (included in Dcbs)

DESCRIPTION: Greenish-gray to gray sandstone, commonly crossbedded; red siltstone and shale at top and base; approximately 450 feet thick; type section is located along the west bank of the Lehigh River east-northeast of the town of Packerton, Carbon County.

BEDDING: Well bedded; thin to medium bedded; sometimes flaggy.

FRACTURING: Joints are well developed; moderate to wide spacing; near horizontal to steeply dipping; open.

WEATHERING: Moderately resistant; moderate depth of weathered bedrock; fragmentation is tabular to blocky; fragments have a rough and hackly surface; moderately thick mantle.

TOPOGRAPHY: Valley-forming unit; in some areas forms only slight topographic swale; slopes are gentle and stable.

DRAINAGE: Good surface drainage.

POROSITY AND PERMEABILITY: Joint- and bedding-plane openings provide a secondary porosity of low magnitude; low permeability.

GROUNDWATER: Limited aquifer potential; thick sequence of water-bearing sandstone is absent; yields for domestic wells should be adequate.

EASE OF EXCAVATION: Moderately difficult; highly fractured shale near surface should be easy; fast drilling rate.

CUT-SLOPE STABILITY: Good; only slight breakup of shale in steep cuts.

FOUNDATION STABILITY: Good; should be excavated to sound bedrock.

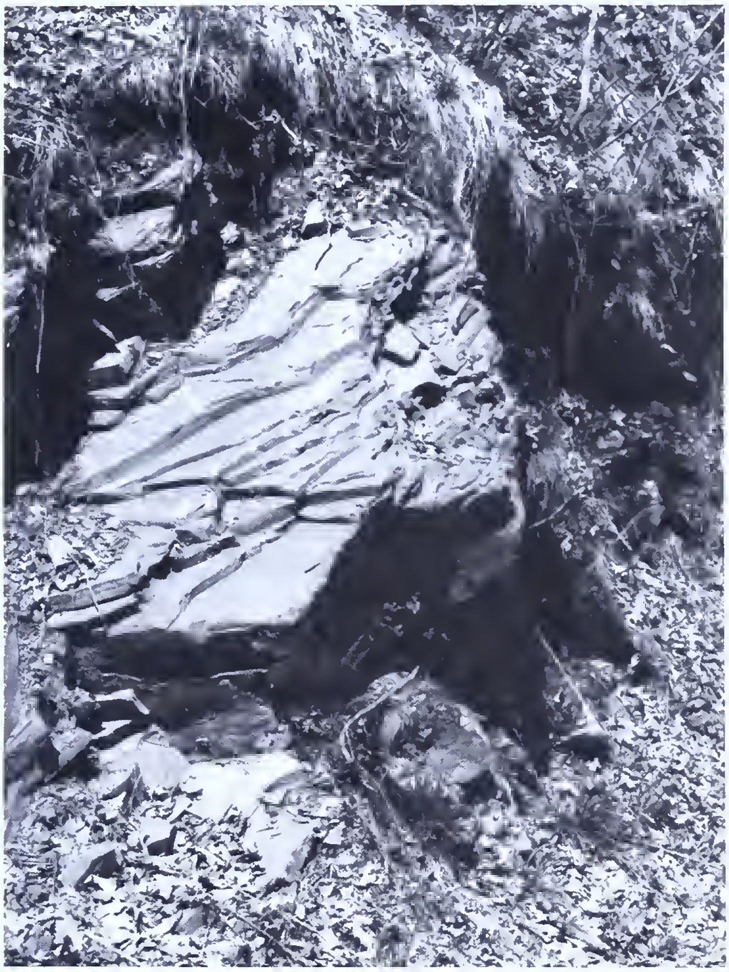
CONSTRUCTION MATERIALS: Good source of random fill.

CATSKILL FORMATION, SHERMAN CREEK MEMBER (Dcsc)

DESCRIPTION: Interbedded grayish-red silty mudstone, sandy siltstone, and reddish-gray to light-olive-gray, very fine to medium-grained, silty, micaceous sandstone; crossbedded; thickness is about 1,200 feet; reference section is along west side of Lycoming Creek at Hepburnville, Lycoming County.

BEDDING: Mudstone is thick bedded to massive; siltstone is medium to thick bedded; sandstone is thin to very thick bedded; extensively crossbedded in most places.

FRACTURING: Joints are well developed, unevenly spaced, highly abundant, steeply dipping, and open.



WEATHERING: Moderately resistant; moderately weathered to a moderate depth; fragmentation is tabular; fragments have rough, hackly surfaces; mantle is thick in most places.

TOPOGRAPHY: Underlies rolling topography characterized by moderate to moderately steep slopes; natural slopes are stable.

DRAINAGE: Good surface drainage.

POROSITY AND PERMEABILITY: Joint- and bedding-plane openings provide a secondary porosity of moderate magnitude; moderate permeability.

GROUNDWATER: Well yields are good to excellent; water quality is generally good, but water may be high in iron.

EASE OF EXCAVATION: Difficult; weathered, highly fractured rock is moderately easy; drilling rate is fast.

CUT-SLOPE STABILITY: Poor to good; where highly weathered and fractured, only poor.

FOUNDATION STABILITY: Good; should be excavated to sound bedrock.

CONSTRUCTION MATERIALS: Good source of road material and random fill.

CATSKILL FORMATION, TOWAMENSING MEMBER (Dct; included in Dcwt)

DESCRIPTION: Very fine to medium-grained sandstone having interbedded shale and siltstone; medium light gray to medium dark gray; crossbedding and ripple marks are present; fossiliferous; maximum thickness is about 600 feet; reference section is along Pa. Route 115 near Effort, Monroe County.

BEDDING: Well bedded; medium to thick.

FRACTURING: Well-developed cleavage and widely spaced joints; joints are both nearly horizontal and nearly vertical; open.

WEATHERING: Moderately resistant; moderately weathered to shallow depth; fragment shape is slabby, flaggy, and blocky; weathered color is olive and grayish orange with some light brown, and yellowish gray to white; overlying mantle is thin to moderate.

TOPOGRAPHY: Underlies high, flat areas.

DRAINAGE: Excellent surface drainage; angular pattern is apparently controlled by rock fractures.

POROSITY AND PERMEABILITY: Primary porosity is low; joint-, bedding-, and cleavage-plane openings form a secondary porosity of moderate magnitude; low permeability.

GROUNDWATER: Maximum potential yield is about 50 gal/min; median yield is 10 gal/min; good water quality, generally soft.

EASE OF EXCAVATION: Difficult; moderate drilling rate.

CUT-SLOPE STABILITY: Good; possibly only fair where rocks are strongly jointed and have well-developed fracture cleavage.

FOUNDATION STABILITY: Good; should be excavated to sound bedrock.

CONSTRUCTION MATERIALS: Good source of random fill; fair source of flagstone; potential for riprap and aggregate.

CATSKILL FORMATION, WALCKSVILLE MEMBER (Dcw; included in Dclw and Dcwt)

DESCRIPTION: Alternating fine- to medium-grained, red sandstone, siltstone, and shale; includes gray and greenish-gray sandstone; some crossbedding and ripple marks; sandstone contains fossil plant fragments; maximum thickness is about 2,500 feet; reference section is along Pa. Route 115 about one-half mile north of Effort, Monroe County.

BEDDING: Sandstone is predominantly medium bedded; some sandstone is thick bedded and some thin bedded; shale is mostly nonbedded and massive; some shale is thin bedded.

FRACTURING: Joints are well developed; widely spaced in sandstone and filled with quartz; cleavage is well developed in some red siltstone.

WEATHERING: Moderately resistant; moderately weathered to moderate depth; natural breakup in shale is hackly and chippy, and in siltstone and sandstone is flaggy, rubbly, and blocky; overlying mantle is moderately thick.

TOPOGRAPHY: Lowland due to predominance of less resistant red shale and siltstone; sandstone forms areas of low local relief.

DRAINAGE: Fair to good surface drainage; trellis to angular drainage pattern.

POROSITY AND PERMEABILITY: Joint-, cleavage-, and bedding-plane openings provide a secondary porosity of moderate to low magnitude; primary porosity in sandstone may be moderate; low permeability.

GROUNDWATER: Sandstones are best water-bearing units; may be under artesian conditions; near-maximum potential is 35 gal/min; water quality is generally good; water may be high in iron.

EASE OF EXCAVATION: Shale and siltstone are moderately easy; sandstone is difficult; moderate drilling rate.

CUT-SLOPE STABILITY: Good in sandstone and siltstone; only fair in shale due to rapid disintegration; slopes cut parallel to bedding may produce dip-slip block slides; drainage maintenance is required.

FOUNDATION STABILITY: Good if shales and siltstones are kept water free; should be excavated to sound bedrock.

CONSTRUCTION MATERIALS: Good source of random fill; potential for flagstone, structural clay products, and lightweight aggregate.

CATTARAUGUS FORMATION (SEE VENANGO FORMATION)

CHADAKOIN FORMATION (Dch)

DESCRIPTION: Medium-gray shale, light-gray to brownish siltstone, fine-grained sandstone, and conglomerate; marine fossils are common; includes "pink rock" of drillers; included in Conneaut Group and "Chemung" of earlier geologists; maximum thickness is about 300 feet; type section is in brick quarries at Jamestown, New York.

BEDDING: Well developed in most places; generally less than 2 inches thick; flaggy and platy.

FRACTURING: Joints are well developed; closely spaced in shale and siltstone; most form a blocky or platy pattern; open and steeply dipping or vertical.

WEATHERING: Shale disintegrates rapidly when exposed to moisture; results in small, platy, triangular fragments; sandstone and siltstone are moderately resistant, and break up into small to medium blocks; mantle is variable in thickness; in glaciated areas of northwestern Pennsylvania, mantle is thick.

TOPOGRAPHY: Plateau of low to medium relief; bedrock topography is masked by glacial material.

DRAINAGE: Surface drainage is moderate to good; in glaciated regions, drainage is poor.

POROSITY AND PERMEABILITY: Interstitial porosity is low in coarser rocks; joint development creates a moderate total effective porosity; low permeability.

GROUNDWATER: Median yield is 4 gal/min; wells greater than 100 feet in depth usually encounter salt water; often a poor aquifer, but adequate for most domestic supplies; salt water and pockets of natural gas are common; yields in Erie County range from 0.1 to 50 gal/min.

EASE OF EXCAVATION: Moderately difficult; drilling rate is moderate.

CUT-SLOPE STABILITY: Fair to good; fairly steep cuts can be maintained in sandstone; siltstone and shale disintegrate rapidly; undercutting of resistant beds can cause poor-quality slopes and result in rockfalls; drainage maintenance is required.

FOUNDATION STABILITY: Good; shale and siltstone should be kept water free; must be excavated to sound bedrock.

CONSTRUCTION MATERIALS: Fair source of brick raw material and fill.

ROCK TEST DATA:
Shale
Unconfined compressive strength = 1,465 to 4,680 lb/in^2

REMARKS: Compressive strength data from John H. Robinson Engineering Inc.

CHAMBERSBURG FORMATION (Oc)

DESCRIPTION: Dark-gray limestone at the top, gray argillaceous limestone in the middle, and dark-gray cobbly limestone at the base; occurs only southwest of the Susquehanna River; maximum thickness is about 770 feet; reference section is along spur of railroad northwest of Kauffman, eastern Franklin County.

BEDDING: Well bedded; thin to flaggy.

FRACTURING: Joints have a platy pattern; well developed; highly fractured; moderate distance between fractures; steeply dipping and open.

WEATHERING: Moderately resistant; moderately to highly weathered to a moderate depth; weathers to pencil-like, jagged fragments up to medium size, elongate plates, and blocks; overlying mantle is thin.

TOPOGRAPHY: Rolling valleys of low relief; natural slopes are gentle and stable.

DRAINAGE: Good surface and minor subsurface drainage.

POROSITY AND PERMEABILITY: Joint and solution openings provide a secondary porosity of low magnitude; low permeability.

GROUNDWATER: Median yield is 5 gal/min; low median yield shows that solution openings are not common; water can be relatively hard.

EASE OF EXCAVATION: Moderately easy; difficult at depth where rock is unweathered; moderate drilling rate.

CUT-SLOPE STABILITY: Fair, due to disintegration when exposed to moisture for a relatively short time.

FOUNDATION STABILITY: Good; should be excavated to sound material; should be investigated thoroughly for sinkholes.

CONSTRUCTION MATERIALS: Good source of road material and fill.

CHEMUNG FORMATION (SEE CHADAKOIN FORMATION, GIRARD SHALE, NORTHEAST SHALE, AND LOCK HAVEN, SCHERR, AND FOREKNOBS FORMATIONS)

CHICKIES FORMATION, HELLAM MEMBER (included in €ch)

DESCRIPTION: Coarse cobble conglomerate composed of well-rounded cobbles 3 to 6 inches in diameter in a finer quartz matrix that firmly cements them; milky white quartz pebbles; pebbles up to one-half inch are common; interbedded with quartzite; approximately 600 feet thick; reference section is in High Rock, York County.

BEDDING: Moderately well to well bedded; thick to massive.

FRACTURING: Joint surfaces show a blocky pattern; moderately to highly developed; sparse; widely spaced and regular; steeply dipping and open.

WEATHERING: Highly resistant; slightly weathered to a shallow depth; weathers to large, rough, blocky fragments, sometimes irregularly shaped; overlying mantle is thin.

TOPOGRAPHY: Ridges of medium relief; natural slopes are steep and stable.

DRAINAGE: Good surface drainage.

POROSITY AND PERMEABILITY: Interconnected, open joints provide a secondary porosity of very low magnitude; very low permeability.

GROUNDWATER: Median yield is 20 gal/min; most water is obtained from the fractured zone of the bedrock near the surface; water levels show a strong seasonal influence; water is soft.

EASE OF EXCAVATION: Difficult; slow drilling rate due to quartz pebbles and cobbles; large boulders may be a problem.

CUT-SLOPE STABILITY: Good; old cut slopes have maintained an apparent stability.

FOUNDATION STABILITY: Good; should be excavated to bedrock for heavy structures.

CONSTRUCTION MATERIALS: Good source of road material, riprap, building stone, and embankment facing.

CHICKIES FORMATION, QUARTZITE (included in €ch and €ul)

DESCRIPTION: Light-gray to white, hard quartzite and quartz schist; "*Scolithus* tubes" are present; thickness is about 400 feet; reference section is at Chickies Rock along the Susquehanna River, in Lancaster County between Marietta and Columbia.

BEDDING: Moderately well to well bedded; thick.

FRACTURING: Joint and cleavage planes display a blocky pattern; moderately well developed; moderately abundant; widely spaced and fairly regular; steeply dipping and open.

WEATHERING: Highly resistant; in most places, slightly to moderately weathered to a shallow depth; hackly, large, irregularly shaped fragments result; overlying mantle is thin.

TOPOGRAPHY: Rough mountains of medium relief; natural slopes are steep and stable.

DRAINAGE: Good surface drainage.

POROSITY AND PERMEABILITY: Joint- and cleavage-plane openings provide a secondary porosity of very low magnitude; very low permeability.

GROUNDWATER: Median yield is 20 gal/min; most water is obtained from the fractured, weathered zone at the top of bedrock; water levels show strong seasonal influence, except for wells in major stream valleys; water is usually soft.

EASE OF EXCAVATION: Difficult; slow drilling rate, in part due to many quartz veins that exceed 12 inches in width; large boulders may be a special problem; locally highly fractured and highly weathered and moderately easy to excavate.

CUT-SLOPE STABILITY: Good; locally, where highly fractured, cut-slope stability is only fair.

FOUNDATION STABILITY: Good; should be excavated to sound material.

CONSTRUCTION MATERIALS: Good source of road material, riprap, building stone, and embankment facing; in some localities, a source of refractory brick; where intensely fractured and weathered, sand is available.

CLINTON GROUP (Sc; included in DSkc)

DESCRIPTION: Includes Keefer and Rose Hill Formations; light- to dark-gray, fossiliferous sandstone; hematitic, oolitic sandstone and shale; light-olive-gray to brownish-gray, fossiliferous shale with some limestone and iron sandstone; 890 feet thick in central Pennsylvania.

BEDDING: Well bedded; thin.

FRACTURING: Joints have a platy pattern; well developed; highly abundant; regular, having a close spacing between fractures; open and steeply dipping to vertical.

WEATHERING: Moderately resistant; moderately weathered to a moderate depth; small, plate-like, rectangular fragments result; overlying mantle is thin.

TOPOGRAPHY: Rolling hills and ridges of medium relief; natural slopes are moderate to fairly steep and stable.

DRAINAGE: Good surface drainage.

POROSITY AND PERMEABILITY: Joint- and bedding-plane openings provide a secondary porosity of low magnitude; low permeability.

GROUNDWATER: Median yield is 12 gal/min; ridge-forming sandstones have very poor topographic position for groundwater development in most areas.

EASE OF EXCAVATION: Moderately difficult; moderate to slow drilling rate; "iron sandstone" beds slow the drilling rate.

CUT-SLOPE STABILITY: Good.

FOUNDATION STABILITY: Good; should be excavated to sound material.

CONSTRUCTION MATERIALS: Good source of road material and fill.

ROCK TEST DATA:
Rose Hill Formation
Water of plasticity = 18 to 24.4%
Drying shrinkage = 1.0 to 4.5%

REMARKS: Test data from USBM.

COBURN FORMATION (included in Ocn and Ocl)

DESCRIPTION: Medium-gray to very dark gray, fossiliferous, shaly limestone; 400 feet thick; reference section is at Coburn, Centre County.

BEDDING: Well bedded; fissile to flaggy in most places; locally thick bedded.

FRACTURING: Joints have a blocky pattern; platy pattern appears in some places; moderately well developed; moderately to highly abundant; fairly regular, having a moderate distance between fractures; mostly open, but some fractures are filled with calcite; steeply dipping to vertical.

WEATHERING: Moderately resistant; slightly weathered to a shallow depth; shaly limestone beds appear moderately weathered to a deeper depth; medium-sized blocks commonly result; shaly units weather to small, pencil-like, flat fragments; overlying mantle is moderately thick; bedrock-mantle interface is usually pinnacled.

TOPOGRAPHY: Rolling valley of low relief; natural slopes are gentle and stable.

DRAINAGE: Good subsurface drainage; poor surface drainage; sinkholes are common.

POROSITY AND PERMEABILITY: Joint and solution openings provide a secondary porosity of moderate to high magnitude; high permeability.

GROUNDWATER: Industrial and public groundwater supplies are available; median yield is approximately 130 gal/min; usually of good quality but easily contaminated; hardness may be high; hydrogen sulfide is sometimes present.

EASE OF EXCAVATION: Difficult; bedrock pinnacles are a special problem; moderate drilling rate.

CUT-SLOPE STABILITY: Good; fair to poor in shaly limestone beds that are susceptible to moisture and have a short-term stability; steeply dipping beds inclined toward the construction are only fair.

FOUNDATION STABILITY: Fair; should be excavated to sound material and should be investigated for possible collapse areas.

CONSTRUCTION MATERIALS: Good source of road material and fill.

ROCK TEST DATA:
Specific gravity = 2.70
Absorption = 0.32%

REMARKS: Test data from PDT.

COCALICO FORMATION, SANDSTONE MEMBER (included in Oco)

DESCRIPTION: Yellowish-brown, argillaceous and quartzose sandstone; entire formation is approximately 1,000 feet thick; reference section is along Cocalico Creek, Lancaster County.

BEDDING: Well bedded; thick.

FRACTURING: Joints have a blocky pattern; well developed; moderately abundant; evenly spaced, having a moderate distance between fractures; open and vertical.

WEATHERING: Highly resistant; slightly weathered to a shallow depth; weathering results in large, irregularly shaped blocks.

TOPOGRAPHY: Rolling valleys of medium relief; natural slopes are moderate and stable.

DRAINAGE: Good surface drainage.

POROSITY AND PERMEABILITY: Joint- and bedding-plane openings provide a secondary porosity of moderate magnitude; low permeability.

GROUNDWATER: Yields of 10 to 15 gal/min are obtained from most wells; fracture openings decrease in number and size as the depth increases; most wells receive water from yielding zones less than 200 feet deep; well development by surging and bailing with a commercial chemical has been determined to be an effective tool for increasing well yields.

EASE OF EXCAVATION: Moderately easy; moderate to slow drilling rate.

CUT-SLOPE STABILITY: Good to fair; steep cuts have been observed.

FOUNDATION STABILITY: Good; should be excavated to sound material.

CONSTRUCTION MATERIALS: Good source of road material, riprap, and fill.

ROCK TEST DATA:
Permeability = 0 to 1.5 ft/day, solid rock.

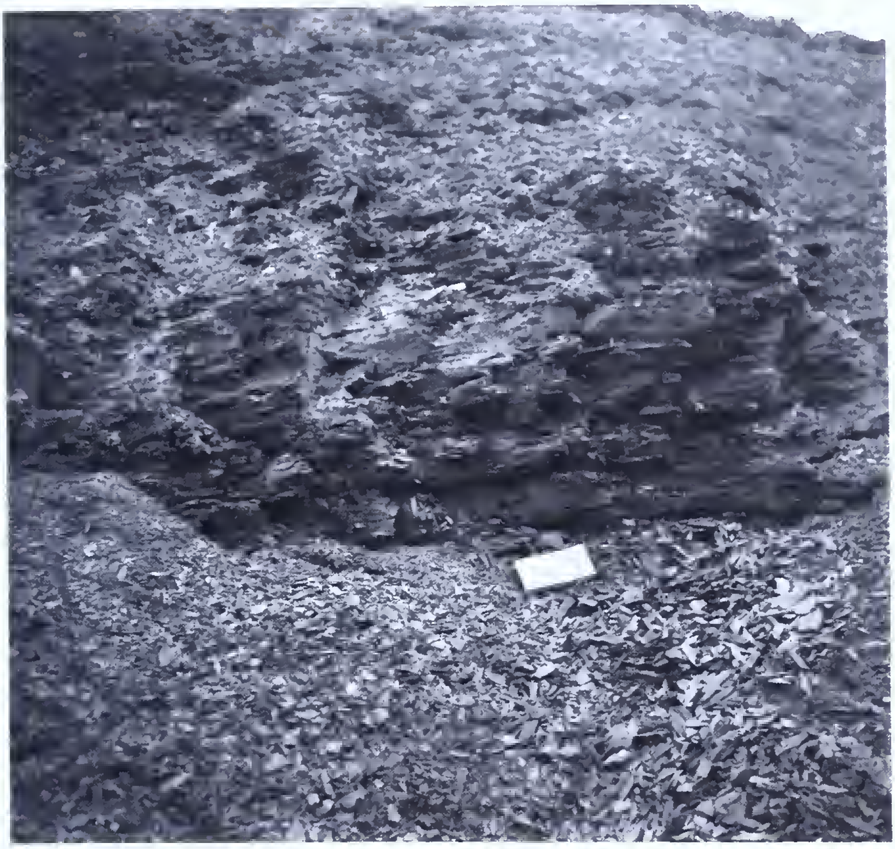
REMARKS: Test data from SCS.

COCALICO FORMATION, SHALE MEMBER (included in Oco)

DESCRIPTION: Dark-gray shale, highly phyllitic; includes some interbedded green and purple shale; entire formation is approximately 1,000 feet thick.

BEDDING: Moderately well bedded; thin.

FRACTURING: Joints have a seamy to platy pattern; well developed and highly abundant; variably spaced, having a close distance between fractures; open and steeply dipping.



WEATHERING: Slightly resistant; moderately to highly weathered to a moderate to deep depth; weathering results in a loose rubble made up of pencil-like fragments to rectangular plates; mantle is thin.

TOPOGRAPHY: Rolling valleys of medium relief; natural slopes are moderate and stable.

DRAINAGE: Good surface drainage.

POROSITY AND PERMEABILITY: Joint-, fault-, and bedding-plane openings provide a secondary porosity of low magnitude; low permeability.

GROUNDWATER: Yields of 10 to 50 gal/min are obtained from most wells; most favorable location for obtaining high-yielding well is upland stream valley; fracture openings decrease in number and size as depth increases; most wells receive water from yielding zones less than 200 feet deep; surging and bailing improves yields; addition of a commercial well conditioner and surging are recommended.

EASE OF EXCAVATION: Moderately easy; slight rebound may be a special problem; fast drilling rate; thin sandstone interbeds slow the drilling rate.

CUT-SLOPE STABILITY: Fair, due to disintegration when exposed to moisture for a relatively short time.

FOUNDATION STABILITY: Good; should be excavated to sound material.

CONSTRUCTION MATERIALS: Good source of road material and fill; good source of raw material for brick.

ROCK TEST DATA:
Water of plasticity = 20 to 26%
Drying shrinkage = 1.0 to 1.5%

REMARKS: Test data from USBM.

COCKEYSVILLE MARBLE (Xc)

DESCRIPTION: Medium- to coarse-grained, white to light-gray marble, often banded with flakes of golden-brown phlogopite; approximately 400 feet thick; reference section is in quarry near village of Chatham, Lancaster County.

BEDDING: Well bedded in thick beds.

FRACTURING: Joints have a blocky pattern; well developed; moderately abundant; regular; moderately spaced; open and in most places vertical.

WEATHERING: Moderately resistant; slightly weathered to a shallow depth; smooth, sandy-textured, large blocks result from long, continued weathering; overlying mantle is variable in thickness.

TOPOGRAPHY: Low, rolling valleys; natural slopes are gentle and stable.

DRAINAGE: Good surface and subsurface drainage.

POROSITY AND PERMEABILITY: Joint and solution channels produce a secondary porosity of moderate to high magnitude; high permeability.

GROUNDWATER: Yields of up to 1,000 gal/min or more are obtainable.

EASE OF EXCAVATION: Difficult; bedrock pinnacles may be encountered; fast drilling rate.

CUT-SLOPE STABILITY: Good.

FOUNDATION STABILITY: Good; sinkhole and bedrock pinnacle investigations should be made.

CONSTRUCTION MATERIALS: Good source of road material, riprap, building stone, embankment facing, and fill.

COEYMANS FORMATION (included in Drc)

DESCRIPTION: Gray, sandy and clayey limestone and gray, fine- to coarse-grained calcareous sandstone and quartz-pebble conglomerate;

amount of limestone decreases westward; maximum thickness is 90 feet; reference section is in Hartmans Cave, southeast slope of Godfrey Ridge at elevation 650 feet, 0.85 mile northeast of Stormville Church, Monroe County.

BEDDING: Well bedded; planar and crossbedded; some lenticular beds.

FRACTURING: Highly developed cleavage and steeply and shallowly dipping joints; uneven, blocky pattern; closely spaced except in western part of outcrop area, where they are very closely spaced.

WEATHERING: Moderately weathered to a shallow depth except in western part of outcrop area, where formation is highly weathered and leached; weathered surface is smooth to angular; fragments are blocky to shaly, 2 inches to more than 5 feet in diameter; fragments are completely disintegrated in western part of outcrop area; overlying mantle is moderately thick.

TOPOGRAPHY: Forms ridge flanks of moderate relief with fairly steep and stable natural slopes.

DRAINAGE: Good surface drainage, except in deeply leached, porous areas to the west, where surface drainage is moderate.

POROSITY AND PERMEABILITY: Joint-, cleavage-, and bedding-plane openings provide a moderate secondary porosity and permeability in unweathered rock.

GROUNDWATER: Median yield is 10 gal/min; best expected yields are from wells in sandstone and limestone; water from limestone is hard and has a reported specific conductance of 325 to 425 micromhos at 25°C.

EASE OF EXCAVATION: Moderately difficult, except easy where deeply weathered and leached; drilling rate is moderate; in weathered zones, drilling rate is fast.

CUT-SLOPE STABILITY: Moderately stable in steep cuts in fresh rock; some rockfall and shale-chip debris sliding; poor stability where deeply leached and weathered.

FOUNDATION STABILITY: Excellent in unweathered bedrock; fair to poor where deeply weathered, requiring special foundation design.

CONSTRUCTION MATERIALS: Limestone has been quarried for agricultural lime; shale and sandstone are good source of random fill and rock fill.

CONEMAUGH GROUP (IPc)

DESCRIPTION: The Conemaugh Group (undivided) is shown only in the Broad Top area in south-central Pennsylvania; elsewhere the rocks in this interval are separated into the Glenshaw and Casselman Formations. The type area is along the Conemaugh River in western Pennsylvania. The Conemaugh is a heterogeneous unit composed of alternating layers of shale, sandstone, limestone, coal, and underclay; sandstone is commonly coarse grained and conglomeratic; shale varies from greenish gray and sandy to black; contains few thin coals and underclays; gray, freshwater limestone occurs in upper part.

BEDDING: Mostly well bedded; thickness of beds varies with lithology, ranging from a fraction of an inch to several feet; very poor bedding in underclay; sandstone may be massive; shale is thin and fissile; limestone is thin.

FRACTURING: Joints are poorly to moderately well formed; moderate distribution; closely to moderately spaced; open and vertical; effects of faulting may be severe; subsidence fractures may be encountered where underground coal and clay mining has taken place.

WEATHERING: Sandstone and limestone are moderately resistant; underclay and coal weather extensively and deeply; disintegration forms rubble consisting of very small plates and small, irregular blocks; overlying mantle is thin.

TOPOGRAPHY: Rolling to rough ridges and hills of medium relief; areas having steep structural dips display deeper, narrower stream valleys; sandstone has noticeable effect on relief and direction of topographic features; moderate to steep natural slopes are stable.

DRAINAGE: Surface drainage is good.

POROSITY AND PERMEABILITY: Primary porosity of sandstone and conglomeratic sandstone is high in most places; limestone and other rocks have a secondary porosity created by jointing; effective porosity and permeability may be high.

GROUNDWATER: Yields are highly variable depending on local effective porosity; care should be taken in well construction to prevent contamination of groundwater supplies in mined-out coal areas; water is of fair quality; high iron content is a common problem.

FOUNDATION STABILITY: Fair to good; should be excavated to sound material; careful attention should be directed to precise location of mined-out coal areas in order to prevent subsidence under heavy loads.

CUT-SLOPE STABILITY: Fair; disintegration of shale under resistant sandstone causes rockfalls and slumps; cuts in massive sandstone can be nearly vertical.

EASE OF EXCAVATION: Heavily weathered coal and shale are easily excavated; sandstone may be difficult; drilling rate is fast to moderate.

CONSTRUCTION MATERIALS: Good source of road material and fill; sandstone is a source of building stone and embankment facing if not platy and thin bedded.

CONESTOGA FORMATION (OꞒc)

DESCRIPTION: Medium-gray, impure limestone having black, graphitic shale partings; conglomeratic at base; in Chester Valley includes micaceous limestone, phyllite, and alternating dolomite and limestone; total thickness is unknown, but is at least 300 feet thick; reference section is along Conestoga Creek south of Lancaster, Lancaster County.

BEDDING: Crudely bedded to poorly bedded; thin; highly crumpled.

FRACTURING: Joints have an irregular pattern; poorly formed; moderately abundant; widely spaced, having an uneven regularity; many are open but some are filled with quartz and calcite.

WEATHERING: Moderately resistant; slightly weathered to a shallow depth; variably weathered (impure layers weather to a higher relief); large, irregularly shaped fragments result; mantle thickness is highly variable and may be extremely thick; interface between bedrock and mantle is pinnacled in most places.

TOPOGRAPHY: Rolling valleys and hills of low relief; natural slopes are gentle and stable.

DRAINAGE: Good surface drainage and minor subsurface drainage; few sinkholes.

POROSITY AND PERMEABILITY: Joint and some solution-channel openings provide a secondary porosity of low magnitude; moderate to low permeability.

GROUNDWATER: Median groundwater yield is 25 gal/min; some wells encounter solution openings for very large yields; water may be very hard.

EASE OF EXCAVATION: Difficult; bedrock pinnacles and numerous quartz veins are special problems; fast drilling rate; quartz veins slow the drilling rate.

CUT-SLOPE STABILITY: Good.

FOUNDATION STABILITY: Good; thorough investigation for possible collapse areas should be undertaken.

CONSTRUCTION MATERIALS: Good source of road material, riprap, building stone, and fill.

ROCK TEST DATA:
Specific gravity = 2.70 to 2.71
Absorption = 0.12 to 0.40%
Compressive strength = 182 to 600 tons/ft^2
(Decomposed micaceous limestone, broken limestone, and solid micaceous limestone)

REMARKS: Compressive strength tests from Conwell and Company; other test data from PDT.

CONNEAUT GROUP (SEE CHADAKOIN FORMATION AND GIRARD SHALE)

CORRY SANDSTONE (included in MDcr, MDsr, and MDso)

DESCRIPTION: Very fine to medium-grained sandstone; crossbedded; sandstone is yellowish white and buff gray; may contain some pebbles; maximum thickness is about 30 feet; named for outcrops near borough of Corry in southeastern Erie County.

BEDDING: Well bedded; generally massive; may contain thin beds near top of unit.

FRACTURING: Joints are well formed, sparse, widely spaced, open, and vertical.

WEATHERING: Moderately to slightly resistant; highly weathered to a moderate depth; weathered surfaces are characteristically yellow brown.

TOPOGRAPHY: Valley floor of major rivers in Venango County; upland of low relief in Erie County; slopes are gentle and stable.

DRAINAGE: Surface drainage is good.

POROSITY AND PERMEABILITY: Primary and secondary porosity present; moderate effective porosity and permeability.

GROUNDWATER: Generally good aquifer; median yield is 15 gal/min; yields in Erie County range from 2 to 40 gal/min.

EASE OF EXCAVATION: Difficult to moderately easy; thin, platy upper beds are rippable; drilling rate is moderate.

CUT-SLOPE STABILITY: Good.

FOUNDATION STABILITY: Good.

CONSTRUCTION MATERIALS: Good source of riprap, fill, and dimension stone; where thin bedded, a source of flagstone.

CUSSEWAGO SANDSTONE (included in MDbr, MDcr, MDsr, MDso, and MDbv)

DESCRIPTION: Fine-grained, micaceous, light-gray, tightly cemented sandstone interbedded with medium-dark-gray micaceous siltstone; basal portion of formation is coarse-grained, light-gray, poorly cemented sandstone interbedded with fine-grained micaceous sandstone; quartz and chert pebbles are present in coarse-grained sandstone; maximum thickness is 100 feet; reference section is located in the Cussewago Creek valley in Crawford County; the term "white sand" has been used by drillers in referring to this rock unit.

BEDDING: Well bedded to poorly bedded; thin to thick.

FRACTURING: Joints are well formed and widely spaced, have a blocky pattern, and are open and vertical.

WEATHERING: Moderately to slightly resistant; deep weathering occurs where poorly cemented; loose sand may be 40 feet thick; mantle, including glacial till, is thin to thick.

TOPOGRAPHY: In Mercer and Venango Counties, forms valleys of low relief where natural slopes are gentle and stable; in Crawford, Erie, and Warren Counties, forms uplands characterized by steep slopes.

DRAINAGE: Surface drainage is good.

POROSITY AND PERMEABILITY: Light-gray, poorly cemented sandstone at base is highly porous, whereas tightly cemented sandstone at top of formation has low porosity; permeability is high in "loose sand" and low in tightly cemented sandstone.

GROUNDWATER: Water-bearing characteristics are directly related to thickness of coarse-grained, poorly cemented sandstone; median yield is 20 gal/min; some wells yield over 100 gal/min; the Cussewago Sandstone is the lowermost consistently freshwater aquifer in Mercer and Venango Counties; good quality, generally soft and low in iron.

EASE OF EXCAVATION: Difficult where sandstone is tightly cemented and fractures are widely spaced; easy in porous, "loose" sand; drilling rate is moderate to fast; loose sand may be a special problem.

CUT-SLOPE STABILITY: Good to poor depending on the presence or absence of "cement" material.

FOUNDATION STABILITY: Good; must be excavated to sound bedrock.

CONSTRUCTION MATERIALS: Good source of fill; tightly cemented sandstone and siltstone may be source of embankment facing and building stone.

CUYAHOGA GROUP (Mc; included in Msc, MDsr, and MDso)

DESCRIPTION: Medium-gray siltstone and dark-gray shale containing interbedded light-gray sandstone; marine fossils are common; includes, in descending order: *Meadville Shale*—medium- to dark-gray shale, siltstone, lenses of fine-grained sandstone, and local beds of limestone; *Sharpsville Sandstone*—very fine grained, light-gray sandstone and medium- to dark-gray shale and siltstone; *Orangeville Shale*—dark-gray shale, locally containing some siltstone; maximum thickness is about 240 feet; reference section is along the Shenango River at Sharpsville and from Big Bend to Jamestown, Mercer County.

BEDDING: Well bedded; sandstone is flaggy; siltstone and limestone are thin; shale is fissile.

FRACTURING: Joints are well developed in sandstone, in places abundant, regular, closely spaced, open, and steeply dipping; joints in shale and siltstone are fewer, widely spaced, open, and steeply dipping.

WEATHERING: Shale is only slightly resistant, eroding so rapidly that exposures are poor; iron staining is common; siltstone is slightly more resistant; sandstone is highly resistant, breaking into slabs that have a characteristic conchoidal fracture; overlying mantle is moderately thick.

TOPOGRAPHY: River valleys of low relief and small protruding hills; natural slopes are gentle and stable.

DRAINAGE: Surface drainage is good.

POROSITY AND PERMEABILITY: Joints provide a secondary porosity of low magnitude; low permeability.

GROUNDWATER: Where the Sharpsville Sandstone contains thick beds of fine-grained sandstone and siltstone it is an important aquifer having a maximum median yield of 50 gal/min and an estimated optimum yield of 115 gal/min; the Meadville Shale and Orangeville Shale are poor aquifers, having estimated optimum yields of 75 and 15 gal/min, respectively; in Erie County yields range from 5 to 62 gal/min; locally contains saline water; water hardness decreases in the 200- to 300-foot depth range because water circulating at that depth has moved through enough shale to be softened.

EASE OF EXCAVATION: Moderately easy in shale; difficult in sandstone and siltstone.

CUT-SLOPE STABILITY: Good, except where excessive undercutting of resistant sandstone occurs and rockfalls and slump are common.

FOUNDATION STABILITY: Good; should be excavated to sound bedrock; special attention to drainage design should be made.

CONSTRUCTION MATERIALS: Good source of fill.

ROCK TEST DATA:

Orangeville Shale

DIRECT SHEAR TEST:

No. of tests	Normal load (lb/in^2)	Shear strength (lb/in^2)								
		Min.	Max.	Ave.	Min.	Max.	Ave.	Min.	Max.	Ave.
6	0	38	198	147	51.2	60.7	57.6	101	240	169
6	100	224	413	367						
6	200	334	555	457						
3	0	108	265	205	49.4	60.9	54.6	132	253	208
3	100	299	407	355						
3	200	468	509	492						

Sharpsville Sandstone

DIRECT SHEAR TEST:

No. of tests	Normal load (lb/in^2)	Shear strength (lb/in^2)								
		Min.	Max.	Ave.	Min.	Max.	Ave.	Min.	Max.	Ave.
3	0	548	965	697	66.6	76.9	71.9	608	888	722
3	100	898	1046	1097						
3	200	1040	1587	1345						

REMARKS: Test data from USCE.

DECKER FORMATION (included in Sdp and DSop)

DESCRIPTION: Variable lithology; lenses and beds of medium- to light-gray, calcareous sandstone and siltstone, quartz-pebble conglomerate, and arenaceous fine- to coarse-grained limestone near the Delaware River, grading westward to silty, finely arenaceous limestone, calcareous siltstone, fine-grained calcareous sandstone, and shale; includes about 20 feet of sandstone, shale, and siltstone of the Andreas Red Beds at the top; thickness is approximately 95 feet; reference section is in southeast part of Herbert R. Imbt quarry, Bossardsville, Monroe County.

BEDDING: Moderately well bedded; fissile to medium; less than 0.25 inch to 2 feet; limestones are irregularly laminated.

FRACTURING: Joints and cleavage are highly developed and closely spaced, 2 inches to 2 feet, in an irregular pattern; fractures are generally open 1 to 10 mm; some are filled with calcite.

WEATHERING: Generally deeply weathered and leached, except northeast of the glacial border where it is weathered to a moderate depth; overlying mantle is moderately thick to thick, in many places dominantly made up of boulder colluvium from the Palmerton Formation.

TOPOGRAPHY: Underlies valley bottoms and ridge flanks of low to moderate relief; natural slopes are moderately steep and moderately stable.

DRAINAGE: Good surface drainage.

POROSITY AND PERMEABILITY: Low to moderate secondary porosity created by joint- and bedding-plane openings in fresh, unweathered rock below leached zone; low to moderate permeability.

GROUNDWATER: Low to moderate aquifer potential; reported yields of 8 to 10 gal/min from wells 150 to 325 feet deep; best expected yields are from limestone.

EASE OF EXCAVATION: Easy where deeply weathered and leached; moderately difficult in unweathered bedrock; drilling rate is moderate to fast.

CUT-SLOPE STABILITY: Generally fair; poor in deeply weathered and leached bedrock where cut slopes are subject to slumping and debris sliding.

FOUNDATION STABILITY: Fair; should be excavated to sound material; may require special foundation support design in some areas.

CONSTRUCTION MATERIALS: Limestone in eastern part of outcrop belt is source of aggregate.

DIABASE (Trd)

DESCRIPTION: Diabase occurs in Pennsylvania primarily as dikes and sheets; the dikes are generally 5 to 100 feet thick and the sheets much thicker; in most places, the rock is dark gray to black, dense, and very fine grained, and consists of 90 to 95 percent labradorite and augite; reference section is at Devils Den in Gettysburg National Park, Adams County.

BEDDING: None.

FRACTURING: Joints have a blocky pattern; well developed; moderately abundant; regularly spaced, having a moderate distance between fractures; open and steeply dipping.

WEATHERING: Highly resistant; slightly weathered to a shallow depth; weathering produces large, rounded boulders mixed with a thin mantle.

TOPOGRAPHY: Undulating hills of medium relief; natural slopes are moderately steep and stable; dikes form ridges.

DRAINAGE: Fair surface drainage.

POROSITY AND PERMEABILITY: Joint openings provide a very low secondary porosity; low permeability.

GROUNDWATER: Median yield is 5 gal/min; yields are usually obtained from the fractured, weathered zone at the top of bedrock; water levels show strong seasonal influence.

EASE OF EXCAVATION: Difficult; large boulders are a special problem; slow drilling rate.

CUT-SLOPE STABILITY: Good; cut-slope stability is adversely influenced by local intense fracturing and depth of cut.

FOUNDATION STABILITY: Good; should be excavated to sound material.

CONSTRUCTION MATERIALS: Good source of road material, riprap, embankment facing, fill, and building stone.

ELBROOK FORMATION (Ꞓe)

DESCRIPTION: Light-gray to yellowish-gray, finely laminated, siliceous limestone having interbeds of dolomite; cherty; thickness is about 3,000 feet; reference section is at Elbrook, Franklin County.

BEDDING: Well bedded; mostly thick, but flaggy and massive beds also occur.

FRACTURING: Joint pattern is irregular and moderately developed; joints are moderately abundant and irregularly spaced, having a wide to moderate distance between fractures; most are open but some are filled with quartz and calcite; steeply dipping.

WEATHERING: Moderately resistant; moderate weathering to a shallow depth; small, flat fragments ranging to large boulders result; the overlying mantle is thin to moderately deep; bedrock-mantle interface is characterized by pinnacles.

TOPOGRAPHY: Rolling valley of low relief; natural slopes are gentle and stable.

DRAINAGE: Good subsurface drainage; little surface drainage.

POROSITY AND PERMEABILITY: Solution channels provide a secondary porosity of moderate magnitude; moderate to high permeability.

GROUNDWATER: Median yield is 30 gal/min.

EASE OF EXCAVATION: Difficult; bedrock pinnacles are a special problem; fast drilling rate; locally, chert slows the drilling rate.

CUT-SLOPE STABILITY: Good.

FOUNDATION STABILITY: Good; thorough investigation for sinkholes and pinnacle bedrock surface should be undertaken.

CONSTRUCTION MATERIALS: Good source of road material, riprap, and fill.

ROCK TEST DATA:
Specific gravity = 2.61 to 2.76
Absorption = 0.26 to 0.80%

REMARKS: Test data from PDT.

EPLER FORMATION (Oe; included in Ob)

DESCRIPTION: Very finely crystalline, medium-gray limestone interbedded with gray dolomite; coarsely crystalline limestone lenses are present; approximately 1,000 feet thick; reference section is along the Reading Railroad about 0.3 mile west of the borough of Richland, Lebanon County.

BEDDING: Moderately well bedded to well bedded; thin to flaggy.

Indian Echo Cave, Epler Formation.

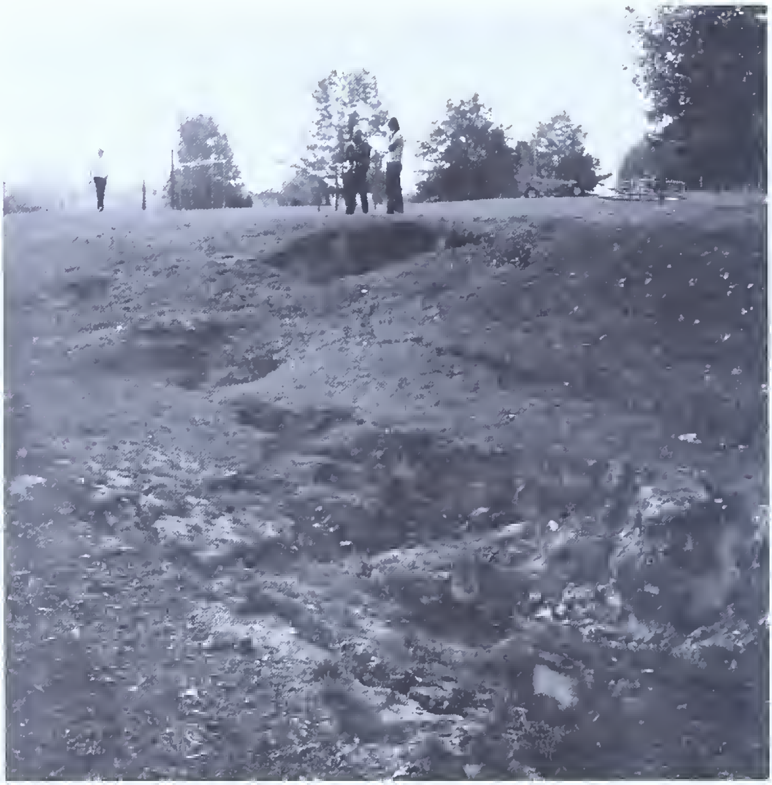
FRACTURING: Joints have a seamy pattern; range from well developed to poorly developed; moderately abundant; moderate distance between fractures; open and steeply dipping to vertical.

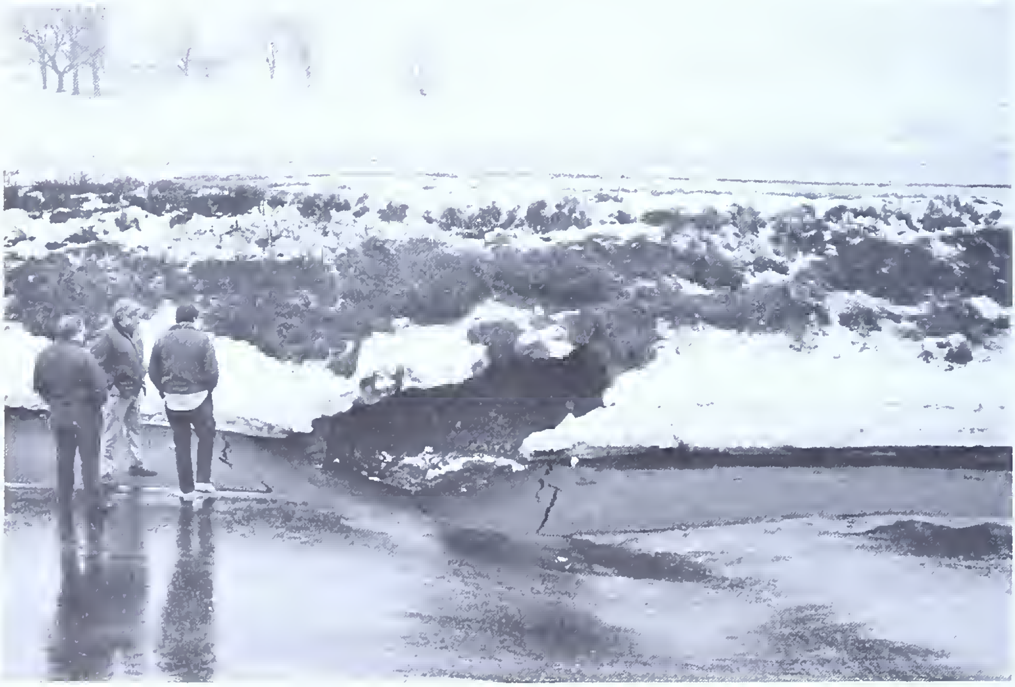
WEATHERING: Moderately resistant; slightly weathered to a shallow depth; small- to medium-sized, flat, rectangular fragments result; overlying mantle varies in thickness, and is sometimes greater than 80 feet thick; bedrock pinnacles are present.

TOPOGRAPHY: Rolling valleys of low relief; gentle and stable natural slopes.

DRAINAGE: Good subsurface drainage; sinkholes and caves are characteristic.

POROSITY AND PERMEABILITY: Joint and solution-channel openings provide a secondary porosity of low to medium magnitude; low permeability.





Sinkholes in the Epler Formation, Derry Township, Dauphin County.

GROUNDWATER: In the Lebanon Valley, medium yield is 15 gal/min; in the Lancaster Valley, Epler is a fair source for public supply and industrial use (51 percent of wells studied have yields greater than 25 gal/min).

EASE OF EXCAVATION: Difficult; bedrock pinnacles are a special problem; fast drilling rate.

CUT-SLOPE STABILITY: Generally good; locally only fair where structure is complex.

FOUNDATION STABILITY: Good; should be excavated to sound bedrock and thoroughly investigated for cavernous areas.

CONSTRUCTION MATERIALS: Good source of road material, riprap, building stone, flagstone, embankment facing, and fill.

ROCK TEST DATA:
Absorption = 0.16 to 0.62%
Specific gravity (bulk, saturated surface—dry) = 2.77

REMARKS: Test data from USCE; limestone samples were 1 to 2 inches in size.

ESOPUS FORMATION (included in Dbe)

DESCRIPTION: Very fine to coarse-grained, gray to olive-gray, hard siltstone and medium- to dark-gray silty shale; thickness is 180 feet, thinning westward to 43 feet; reference section is at the extreme southwest end of an abandoned quarry near East Stroudsburg, Monroe County, near intersection of Interstate Route 80 and U.S. Route 209 north, dirt road to right before Holiday Inn on left, under Interstate 80.

BEDDING: Well bedded, having sharp bedding-plane contacts; fissile in shale; thin to medium in siltstone; ranges from 1/2 inch to 2 feet in thickness but is mostly 1 to 4 inches thick.

FRACTURING: Joints are highly developed; very closely to closely spaced in a distinctive blocky and platy pattern; joints are nearly at a right angle to bedding and have narrow to moderately narrow openings.

WEATHERING: Moderately weathered to a shallow depth; more deeply weathered to the west; hard siltstone weathers easily by breaking along very closely spaced fractures into blocky, platy pieces 2 to 6 inches long; overlying mantle is moderately thick, and in many places contains boulder colluvium from the Palmerton Formation.

TOPOGRAPHY: Occupies flanks of low ridges capped by the Palmerton and Oriskany Formations; natural slopes are fairly steep and stable.

DRAINAGE: Good surface drainage.

POROSITY AND PERMEABILITY: Joint- and bedding-plane openings provide a moderate secondary porosity in unweathered rock; permeability is moderate to high.

GROUNDWATER: Average well yield is 8 to 10 gal/min from wells 200 to 300 feet deep; one well in shale reportedly yielded 73 gal/min, had a hardness of 4 gpg, and a specific conductance of 175 micromhos at 25°C.

EASE OF EXCAVATION: Moderately difficult; weathered zones in western part of outcrop belt are easy; very closely spaced, blocky fracture pattern in siltstone facilitates excavation in some areas; drilling rate is moderate to fast.

CUT-SLOPE STABILITY: Fair in western part of outcrop belt where deeply weathered; good in the east, but some rockfall may occur in jointed siltstone.

FOUNDATION STABILITY: Good when excavated to sound bedrock.

CONSTRUCTION MATERIALS: Good source of random fill in selected areas where easily excavated.

FELSIC GNEISS, HORNBLENDE-BEARING; FELSIC GNEISS, PYROXENE-BEARING (SEE GRANITIC GNEISS)

FOREKNOBS FORMATION (Df)

DESCRIPTION: Brownish-gray sandstone, siltstone, and shale; marine fossils; local quartz-pebble conglomerate; some reddish-gray, nonmarine siltstone; maximum thickness is about 2,300 feet; reference section is near Judy Gap, Pendleton County, West Virginia, in cuts along road beside Briery Gap Run.

BEDDING: Well bedded; massive.

FRACTURING: Joints are well developed and open; closely spaced and regular in shale, moderately spaced in sandstone, siltstone, and conglomerate; blocky pattern in sandstone, siltstone, and conglomerate; platy pattern in shale.

WEATHERING: Shale disintegrates rapidly, resulting in small, platy fragments; sandstone, siltstone, and conglomerate are moderately resistant, and breakup results in medium- to large-sized blocks; mantle is variable in thickness.

TOPOGRAPHY: Foothills of the Allegheny Front; fairly steep natural slopes are stable.

DRAINAGE: Good surface drainage.

POROSITY AND PERMEABILITY: Low primary porosity; joint openings provide a secondary porosity and an overall effective porosity of moderate magnitude; moderate permeability.

GROUNDWATER: Yields in excess of 300 gal/min have been reported; soft water of good to excellent quality.

EASE OF EXCAVATION: Generally difficult; weathered shale is easy; moderate to fast drilling rate.

CUT-SLOPE STABILITY: Good in sandstone, siltstone, and conglomerate; only fair in shale due to rapid disintegration.

FOUNDATION STABILITY: Good; should be kept water free; should be excavated to sound rock.

CONSTRUCTION MATERIALS: Good source of random fill; shale may be source of ''common'' brick raw material.

FRANKLIN MARBLE (fm)

DESCRIPTION: Fine- to medium-grained, white marble; contains specks of graphite; approximately 100 feet thick; reference section is in a small quarry one-half mile west of New Berlinville, Berks County.

BEDDING: Well bedded; thick to massive.

FRACTURING: Joints have a blocky pattern; well developed; moderately abundant; regular; moderately spaced; open and nearly vertical.

WEATHERING: Moderately resistant; slightly weathered to a shallow depth; large blocks result; overlying mantle is variable in thickness.

TOPOGRAPHY: Dissected upland; gentle relief and stable slopes.

DRAINAGE: Good surface drainage; solution openings and subsurface drainage occur.

POROSITY AND PERMEABILITY: Joint and solution openings provide a secondary porosity of moderate to high magnitude; high permeability.

GROUNDWATER: Yields of more than 100 gal/min are common; water is hard.

EASE OF EXCAVATION: Difficult; bedrock pinnacles may be encountered; fast drilling rate.

CUT-SLOPE STABILITY: Good.

FOUNDATION STABILITY: Good; thorough investigation for solution openings and possible surface collapse should be undertaken.

CONSTRUCTION MATERIALS: Good source of high-calcium stone, building stone, and fill material.

GABBROIC GNEISS AND GABBRO (gga)

DESCRIPTION: Dark color; medium to fine grained; fresh rock consists of calcic plagioclase, hypersthene or augite, and up to 30 percent quartz.

BEDDING: Banding is poorly developed; bands are massive in thickness.

FRACTURING: Joints have an irregular pattern; moderately to poorly formed; moderate in abundance; widely to moderately spaced; irregular, steeply dipping to vertical, and open.

WEATHERING: Highly resistant; most exposures show slight weathering to a shallow depth; loose material consists of large, rectangular blocks; overlying mantle is thin.

TOPOGRAPHY: Hills of medium relief and undulating surface; natural slopes are fairly steep to steep and stable.

DRAINAGE: Good surface drainage.

POROSITY AND PERMEABILITY: Extremely low primary porosity; joints provide a very low secondary porosity; low permeability.

GROUNDWATER: Median yield is 20 gal/min; median depth is 84 to 94 feet; yields of 36 gal/min or more should be obtainable from wells properly sited and developed.

EASE OF EXCAVATION: Difficult; slow drilling rate.

CUT-SLOPE STABILITY: Good.

FOUNDATION STABILITY: Good; should be excavated to sound material.

CONSTRUCTION MATERIALS: Good source of riprap, building stone, embankment facing, and fill.

GATESBURG FORMATION (€g; includes €gm and €gl)

DESCRIPTION: Gray, coarsely crystalline dolomite having many sandstone interbeds up to 10 feet thick; oolitic; cherty; cryptozoon fossils; includes five members, in descending order: *Mines Member*—gray dolomite containing siliceous "oolites" and chert having cryptozoon structures; *"upper sandstone member"*—cyclic repetitions of sandstone and dolomite; *Ore Hill Member*—fossiliferous, laminated to massive limestone and dolomite; *"lower sandstone member"*—cyclic repetitions of sandstone and dolomite; and *Stacy Member*—crystalline dolomite; at least 1,600 feet thick; reference section is at Gatesburg Ridge, Centre County.

BEDDING: Well bedded; thick to massive.

FRACTURING: Joints have a blocky pattern; moderately well developed; moderately to highly abundant; regularly spaced, having a moderate distance between fractures; open and steeply dipping.

WEATHERING: Moderately resistant; slightly to moderately weathered to a shallow depth; irregularly shaped, medium-sized blocks result from prolonged weathering; in certain areas of Pennsylvania, the overlying mantle is extremely thick; the interface between the bedrock and the mantle is characterized by pinnacles in most places.

TOPOGRAPHY: Rolling valley of low relief; natural slopes are gentle and stable.

DRAINAGE: Good subsurface drainage; little surface drainage.

POROSITY AND PERMEABILITY: Primary porosity in the weathered portion; solution channels provide a secondary porosity of moderate to high magnitude; locally, a very high porosity is encountered; high permeability.

GROUNDWATER: Average yield of 375 gal/min; drilling conditions may be difficult due to flowing sand; water levels are often greater than 100 feet.

EASE OF EXCAVATION: Difficult; bedrock pinnacles are a special problem; moderate drilling rate; numerous sandstone beds slow the drilling rate.

CUT-SLOPE STABILITY: Sandstone units show rapid disintegration when exposed to moisture for a relatively short time; fair to good.

FOUNDATION STABILITY: Good; a thorough investigation for solution channels should be undertaken; must be excavated to fresh bedrock.

CONSTRUCTION MATERIALS: Good source of road material, riprap, embankment facing, fill, and aggregate.

GATESBURG FORMATION, MINES MEMBER (€gm; included in €g)

DESCRIPTION: Medium-gray, coarsely crystalline dolomite; abundant light-gray chert containing black oolites; chert contains silicified cryptozoon fossils; about 250 feet thick; type section is at the village of Mines, 5 miles southwest of Williamsburg, Blair County.

BEDDING: Well bedded; thick to massive.

FRACTURING: Joints have a blocky pattern; moderately well developed; moderately to highly abundant; regularly spaced, having a moderate distance between fractures; open and steeply dipping.

WEATHERING: Moderately resistant; slightly to moderately weathered to a shallow depth; irregularly shaped, medium-sized blocks result from prolonged weathering; interface between bedrock and mantle is characterized by pinnacles in most places.

TOPOGRAPHY: Rolling valley of low relief; natural slopes are gentle and stable.

DRAINAGE: Good subsurface drainage; little surface drainage.

POROSITY AND PERMEABILITY: Solution channels provide a secondary porosity of moderate to high magnitude; may be highly permeable.

GROUNDWATER: Median yield is greater than 100 gal/min; some well yields exceed 1,000 gal/min.

EASE OF EXCAVATION: Difficult; bedrock pinnacles are a special problem; moderate drilling rate.

CUT-SLOPE STABILITY: Fair to good.

FOUNDATION STABILITY: Good; a thorough investigation for solution channels should be undertaken.

CONSTRUCTION MATERIALS: Good source of road material, riprap, embankment facing, fill, and concrete aggregate.

GETTYSBURG FORMATION (Trg)

DESCRIPTION: Reddish-brown shale and soft, red-brown, medium- to fine-grained sandstone; minor amount of yellowish-brown shale and sandstone; may be metamorphosed by intrusive diabase to dark-purple to black argillite; total thickness is about 16,000 feet; reference sections are in vicinity of Gettysburg, Adams County.

BEDDING: Moderately well bedded; thin to flaggy.

FRACTURING: Joints have a blocky pattern; moderately developed; moderately abundant; uneven regularity; closely spaced; steeply dipping; open and filled with quartz and calcite.

WEATHERING: Moderately resistant; moderately weathered to a moderate depth; weathered fragments range in size from elongated and pencil-like to medium-sized, irregularly shaped blocks; smaller fragments result from rapid hydration of minerals in exposed outcrop; overlying mantle is moderately thick.

TOPOGRAPHY: Undulating hills of low relief; natural slopes are moderately steep and stable.

DRAINAGE: Good surface drainage.

POROSITY AND PERMEABILITY: Joint- and bedding-plane openings provide a secondary porosity of moderate magnitude; moderate permeability.

GROUNDWATER: Median yield is 66 gal/min; hardness and total dissolved solids are frequently high.

EASE OF EXCAVATION: Weathered zone may be excavated moderately easily; unweathered rock is difficult; moderate to fast drilling rate except adjacent to diabase where rock is harder and drilling rate slow.

CUT-SLOPE STABILITY: Fair to poor; landslides occur where cut slopes are steep and rocks dip toward cut.

FOUNDATION STABILITY: Good; should be excavated to sound material; good drainage necessary.

CONSTRUCTION MATERIALS: Good source of road material and fill; part of formation is good source of raw material for lightweight aggregate and common brick.

ROCK TEST DATA:
Permeability = 1 to 10 ft/day
Water of plasticity = 18%
Drying shrinkage = 4.0%
Water content = 0.82 to 0.94%

Dry density = 166.1 to 168.3 lb/ft^3
Elastic modulus (Ec) = 0.30 x 10^6 to 0.90 x 10^6 lb/ft^2
Compressive strength = 82.9 to 91.6 tons/ft^2

REMARKS: Permeability data from SCS; other data from USBM.

GETTYSBURG FORMATION, CONGLOMERATE (Trgc)

DESCRIPTION: Coarse quartz conglomerate containing rounded pebbles and cobbles in a matrix of red sand; maximum thickness is 7,300 feet; type section is at Conewago, York County.

BEDDING: Well bedded; thick to massive.

FRACTURING: Joints have a blocky pattern; moderately developed; moderately abundant; regularly spaced, having a moderate distance between fractures; open and steeply dipping.

WEATHERING: Moderately resistant; disintegration ranges from large blocks to individual pebbles, cobbles, and sand grains; overlying mantle is thin.

TOPOGRAPHY: Small hills that are slightly higher than the surrounding countryside; slopes are moderate and stable.

DRAINAGE: Good surface drainage.

POROSITY AND PERMEABILITY: Joint-, bedding-, and fault-plane openings provide a secondary porosity of low magnitude; low permeability.

GROUNDWATER: Median well yield is 11 gal/min for nondomestic wells; maximum well yield of more than 195 gal/min has been reported; generally of satisfactory quality for most purposes.

EASE OF EXCAVATION: Difficult; quartz pebbles and cobbles slow the drilling rate.

CUT-SLOPE STABILITY: Fair; sand matrix disintegrates within several years of exposure.

FOUNDATION STABILITY: Good; should be excavated to solid rock.

CONSTRUCTION MATERIALS: Good source of road material and fill.

GETTYSBURG FORMATION, HEIDLERSBURG MEMBER (Trgh)

DESCRIPTION: Gray to white sandstone having interbeds of red shale and sandstone; some green, gray, and black shale; near diabase sheets these rocks have been altered to white quartzite, white sandstone, and dark-purplish argillite; thickness is 4,800 feet; reference section is in vicinity of village of Heidlersburg, Adams County.

BEDDING: Moderately well bedded, flaggy to thick.

FRACTURING: Joints have a blocky pattern; well developed in sandstones and argillites; moderately abundant; steeply dipping; open.

WEATHERING: Moderately resistant; altered rocks are more resistant; moderately weathered to a shallow depth; weathered fragments are medium-sized blocks and irregularly shaped material; overlying mantle is thin.

TOPOGRAPHY: Undulating hills of low relief; natural slopes are moderately steep and stable.

DRAINAGE: Good surface drainage.

POROSITY AND PERMEABILITY: Primary porosity of moderate magnitude in weathered sandstones, and low magnitude in fresh, unaltered rock; joint- and bedding-plane openings provide a secondary porosity of moderate magnitude; low permeability.

GROUNDWATER: Median yield is 50 gal/min; 90 percent of all nondomestic wells drilled exceeded 18 gal/min from wells drilled to 275 feet or more.

EASE OF EXCAVATION: Weathered material is moderately easy; unweathered rock is difficult; drilling rate is moderate to slow.

CUT-SLOPE STABILITY: Good; harder, altered sandstone and argillite are excellent.

FOUNDATION STABILITY: Good; should be excavated to sound material; good drainage may be required.

CONSTRUCTION MATERIALS: Good source of road material and fill.

ROCK TEST DATA:
Water of plasticity = 21%
Drying shrinkage = 2.0%

REMARKS: Test data from USBM.

GIRARD SHALE (Dg)

DESCRIPTION: Light- to medium-gray, very fine grained shale; few sandy layers; slightly fossiliferous; cone-in-cone structures are present; included in Conneaut Group and "Chemung" by earlier workers; 50 to 200 feet thick in Erie County; named for rocks exposed at Girard, Erie County.

BEDDING: Well developed in most places; generally less than 2 inches thick; flaggy and platy.

FRACTURING: Well developed; closely spaced; platy pattern in most places; open and steeply dipping.

WEATHERING: Shale disintegrates rapidly when exposed to moisture; results in small, platy, irregularly shaped fragments; mantle is variable in thickness.

TOPOGRAPHY: Upland areas; bedrock topography may be masked by glacial material.

DRAINAGE: Surface drainage is moderate to good; may be poor where overlying glacial material is thick.

POROSITY AND PERMEABILITY: Secondary porosity is low; low permeability.

GROUNDWATER: Generally a poor aquifer; median yield is 2 gal/min in Erie County; yield ranges from 0.1 to 50 gal/min.

EASE OF EXCAVATION: Moderately difficult; drilling rate is fast.

CUT-SLOPE STABILITY: Shale disintegrates rapidly; stability is only moderate; drainage maintenance may be required.

FOUNDATION STABILITY: Good; should be excavated to sound bedrock.

CONSTRUCTION MATERIALS: Good source of fill.

GLENSHAW FORMATION (ℙcg)

DESCRIPTION: Heterogeneous unit composed of alternating layers of shale, sandstone, siltstone, limestone, claystone (including underclay), and coal; includes marine shale and limestone, and fine- to coarse-grained, locally conglomeratic sandstone; red beds are common, especially in middle and upper parts; contains a few thin, persistent coals and minor freshwater limestone; thickness ranges from 280 feet in western Washington County to about 375 feet in Somerset County; type area is at Glenshaw (in valley of Pine Creek), Shaler Township, Allegheny County.

BEDDING: Well bedded in most places; thickness of beds varies with lithology, ranging from a fraction of an inch to several feet; sandstone is thick bedded to massive; limestone varies from well bedded to nodular; shale is thin and fissile; very poor bedding in claystone.

FRACTURING: Joints are poorly to moderately well formed; moderate distribution; closely to moderately spaced; open and vertical; subsidence fractures may be encountered where underground coal and clay mining has occurred.

WEATHERING: Sandstone, siltstone, and limestone are moderately resistant; claystone, shale, and coal weather extensively and deeply; disintegration forms rubble consisting of very small plates and small, irregular blocks; overlying mantle is thin.

TOPOGRAPHY: Rolling to narrow ridges and hills of medium relief; areas having steeper structural dips display deeper, narrower stream valleys separated by broad-topped, steep-sided divides; moderate to steep natural slopes are stable except where red beds occur.

DRAINAGE: Surface drainage is good.

POROSITY AND PERMEABILITY: Primary porosity of sandstone is mostly moderate; other rock types produce water through secondary porosity caused by jointing.

GROUNDWATER: Yields of more than 50 gal/min may be expected from sandstone; yields are highly variable depending on local effective porosity; mining operations may disrupt normal groundwater occurrence; care should be exercised in well construction to prevent contamination of groundwater supplies in mined-out areas and in oil- and gas-producing areas; water is of fair quality.

EASE OF EXCAVATION: Heavily weathered coal, shale, and claystone are excavated easily; drilling rate is fast to moderate.

CUT-SLOPE STABILITY: Varies depending on lithology, from poor to fair for red beds to good for sandstone; cuts in thick- to massive-bedded sandstone can be nearly vertical; disintegration of claystone and shale under resistant sandstone and siltstone beds results in rockfalls, slumps, and landslides.

FOUNDATION STABILITY: Fair to good; should be excavated to sound material; heavy structures should not be located on or near claystone because of tendency to deform under load when wet.

CONSTRUCTION MATERIALS: Good source of road material and fill; claystone may provide refractory material; sandstone provides building stone and embankment facing if not platy and thin bedded.

ROCK TEST DATA:

Ames limestone
  Unconfined compressive strength = 4,165 lb/in^2
Ames shale
  Shear (100 lb load normal to bedding) = 361 lb/in^2
  Shear (100 lb load cross angle to bedding) = 468 lb/in^2
  Tensile strength = 2,392 lb/in^2
  Bearing capacity = 8 tons/ft^2
Harlem coal
  Unconfined compressive strength = 1,160 to 1,680 lb/in^2
Pittsburgh red beds
  Shear (normal to bedding) = 320 lb/in^2
  Shear (cross angle to bedding) = 466 lb/in^2
  Unconfined compressive strength = 1,661 lb/in^2
  Tensile strength = 576 lb/in^2
  Bearing capacity = 4 to 8 tons/ft^2
Saltsburg sandstone
  Shear (normal to bedding) = 974 lb/in^2
  Shear (cross angle to bedding) = 1,255 lb/in^2
  Unconfined compressive strength = 9,991 lb/in^2
  Tensile strength = 4,330 lb/in^2
  Bearing capacity = 25 tons/ft^2
  Modulus of elasticity = 1,766,500 lb/in^2 (25% ultimate strength)
Saltsburg siltstone
  Shear (normal to bedding) = 1,110 lb/in^2
  Shear (cross angle to bedding) = 1,377 lb/in^2
  Unconfined compressive strength = 8,838 lb/in^2
  Tensile strength = 5,834 lb/in^2
  Bearing capacity = 15 to 25 tons/ft^2
Mahoning sandstone
  Unconfined compressive strength = 9,462 lb/in^2

REMARKS: Test data from USCE.

GRANITIC GNEISS (gn)

DESCRIPTION: Light buff to light pink; fine to medium grained; most mineral grains are about 1 mm in diameter; primary minerals are quartz, microcline, hornblende (5 to 10 percent), and occasional biotite.

BEDDING: Banding is poorly developed; massive.

FRACTURING: Joints have an irregular pattern; moderately to poorly formed; moderately abundant; widely to moderately spaced; irregular and steeply dipping to vertical; open.

WEATHERING: Highly resistant; slight weathering to a shallow depth; loose material consists of large rectangular blocks; mantle is thin.

TOPOGRAPHY: Hills of medium to high relief; natural slopes are steep and stable.

DRAINAGE: Good surface drainage.

POROSITY AND PERMEABILITY: Joints provide a very low secondary porosity; low permeability.

GROUNDWATER: Median yield is less than 20 gal/min; yields of 35 gal/min or more may be obtainable from wells properly sited and developed; wells should be at least 100 feet deep, but probably not over 200 feet for maximum yield.

EASE OF EXCAVATION: Difficult; slow drilling rate.

CUT-SLOPE STABILITY: Good.

FOUNDATION STABILITY: Good; should be excavated to sound rock.

CONSTRUCTION MATERIALS: Excellent source of road material, riprap, building stone, embankment facing, and fill.

GRANITIC GNEISS AND GRANITE (Xgr)

DESCRIPTION: Light buff to light pink; fine to medium grained; most mineral grains are about 1 mm in diameter; essential minerals are quartz, microcline, hornblende (5 to 10 percent), and some biotite; rocks are extremely resistant to abrasion and rupture; includes Springfield Granodiorite; reference section is on the north slope of South Mountain, Lehigh County.

BEDDING: Banding is poorly developed; bands are massive.

FRACTURING: Joints have an irregular pattern; moderately to poorly formed; moderate in abundance; widely to moderately spaced; steeply dipping to vertical; open.

WEATHERING: Highly resistant to weathering; slightly weathered to a shallow depth; loose material consists of large, rectangular blocks; overlying mantle is thin.

TOPOGRAPHY: Rough hills of medium to high relief; natural slopes are fairly steep to steep and stable.

DRAINAGE: Good surface drainage.

POROSITY AND PERMEABILITY: Low primary porosity; joints provide a low secondary porosity; low permeability.

GROUNDWATER: Median yield is 20 gal/min; yields are usually obtained from the fractured, weathered zone at the top of bedrock; producing fractures are seldom found below 200 feet; water levels show strong seasonal influence; water is usually soft; may have high iron content.

EASE OF EXCAVATION: Difficult; slow drilling rate.

CUT-SLOPE STABILITY: Good.

FOUNDATION STABILITY: Good; should be excavated to sound material.

CONSTRUCTION MATERIALS: Good source of road material, riprap, building stone, embankment facing, and fill.

ROCK TEST DATA:
Unconfined compressive strength = 6,340 to 7,250 lb/in^2 (dry, unweathered gneiss)

REMARKS: Test data from VU.

GRANODIORITE AND GRANODIORITE GNEISS (ggd)

DESCRIPTION: Medium grained; light pink to green; largely quartz, feldspar, and mica; commonly gneissic.

BEDDING: None.

FRACTURING: Joints; blocky pattern; moderately developed; moderately abundant; irregular; widely spaced; open and moderately dipping.

WEATHERING: Highly resistant; slightly weathered to a shallow depth; results in smooth, rounded, large boulders; overlying mantle is thin.

TOPOGRAPHY: Hills; medium relief; natural slopes are fairly steep and stable.

DRAINAGE: Good surface drainage.

POROSITY AND PERMEABILITY: Joints produce a secondary porosity of low magnitude; low permeability.

GROUNDWATER: Yield of 10 gal/min or less may be expected; yields of 25 gal/min or more may be obtained from wells properly sited and developed.

EASE OF EXCAVATION: Difficult; large surface and near-surface boulders hamper excavation; slow drilling rate.

CUT-SLOPE STABILITY: Good.

FOUNDATION STABILITY: Good; should be excavated to sound material.

CONSTRUCTION MATERIALS: Good source of riprap, building stone, embankment facing, and fill.

GRAPHITIC GNEISS (gg)

DESCRIPTION: Light to medium gray; includes the minerals quartz, orthoclase, hornblende, biotite, and graphite; graphite occurs as flakes 1 to 2 mm in diameter, somewhat larger than the usual grain size of the rock, and is disseminated throughout the gneiss; graphite shows a glistening luster which is sometimes a helpful aid in identification of this rock; includes Pickering Gneiss.

BEDDING: Banding is distinct and very common; bands are flaggy in thickness.

FRACTURING: Joints are the most common fractures; platy pattern; well developed; moderately to highly abundant; regular; moderately to closely spaced; open and steeply dipping to vertical.

WEATHERING: Moderately resistant; deeply weathered; sometimes results in disintegration into very small rectangular fragments; overlying mantle is thick.

TOPOGRAPHY: Hills; low to medium relief; natural slopes are gentle to moderate and stable.

DRAINAGE: Good surface drainage.

POROSITY AND PERMEABILITY: Joints produce a secondary porosity; weathered portion has a moderate porosity; low permeability.

GROUNDWATER: Expected yield may be 10 gal/min or less; yields of 35 gal/min or more may be obtained from wells properly sited and developed.

EASE OF EXCAVATION: Weathered portion may be excavated moderately easily; moderate drilling rate.

CUT-SLOPE STABILITY: Due to almost complete disintegration when exposed to moisture for a relatively short time, moderate slope cuts are necessary; only fair cut-slope stability.

FOUNDATION STABILITY: Good; should be excavated to sound material.

CONSTRUCTION MATERIALS: Good source of fill.

GREENE FORMATION (Pg)

DESCRIPTION: Unit consists of shale, some siltstone and sandstone, and minor amounts of shaly limestone, claystone, carbonaceous shale, and thin coal; shale is locally interbedded with siltstone and sandstone; sandstone locally occurs as channel-fill deposits; base of formation is at top of Upper Washington limestone; thickness is variable and may be up to 500 feet; type area is along Dunkard Creek in Greene County, Pennsylvania.

BEDDING: Moderately well developed; thin or flaggy in most places; claystones are generally nonbedded.

FRACTURING: Joints are common; moderately well developed; blocky and platy patterns; regularly spaced at moderate distances; open and vertical.

WEATHERING: Moderately resistant; differential weathering may cause undercutting of tougher units such as sandstone and limestone; rubble normally consists of small- to medium-sized rectangular fragments.

TOPOGRAPHY: Rolling to rough plateau of high relief; natural slopes are stable and steep; large number of small streams separated by short, narrow divides.

DRAINAGE: Surface drainage is good.

POROSITY AND PERMEABILITY: Porosity is moderate in coarse-grained sandstone units; most of the rock is very tight; joints provide secondary porosity of very low magnitude; low permeability.

GROUNDWATER: Median yield is 15 gal/min; yields to 50 gal/min have been reported; water quality is satisfactory for most purposes; high topographic position and lack of extensive thick sandstones make unit undesirable except for domestic wells.

EASE OF EXCAVATION: Except for locally tough sandstone and limestone beds, can be excavated moderately easily; in areas having higher percentage of limestone and sandstone, excavation is difficult.

CUT-SLOPE STABILITY: Poor to fair; claystone disintegrates in a short time when exposed to moisture; undercutting of sandstone and limestone beds occurs; drainage maintenance may be required.

FOUNDATION STABILITY: Fair to good; should be excavated to sound material.

CONSTRUCTION MATERIALS: Good source of road material and fill.

ROCK TEST DATA:
Water of plasticity = 19.2%
Drying shrinkage = 4%

REMARKS: Test data from USBM.

GREENSTONE SCHIST (vs)

DESCRIPTION: Greenish-gray, lustrous phyllite and schist; some finely banded, light greenish gray, dusky yellow green, and grayish yellow green; thickness is generally less than 100 feet, locally up to 150 feet; reference section is in a small quarry about one-half mile east of Mt. Hope Church, Adams County.

BEDDING: None.

FRACTURING: Cleavage has a platy pattern and is well developed, highly abundant, regular, and closely spaced; joints are well developed, irregular to widely spaced, steeply dipping, and closed.

WEATHERING: Moderately resistant; often highly weathered to a moderate depth, resulting in uneven, hackly, small to large plate-like rubble; overlying mantle is thin.

TOPOGRAPHY: Typically occupies local intermountain valleys having gentle slopes.

DRAINAGE: Good surface drainage.

POROSITY AND PERMEABILITY: Cleavage, joint, and fault planes provide a low secondary porosity and permeability.

GROUNDWATER: Where intensely fractured, may yield 10 gal/min or more; usually very small yields are encountered.

EASE OF EXCAVATION: Moderately easy; where quartz veins along cleavage surfaces and joint planes are numerous, excavation is difficult; drilling rate is fast to slow depending on quantity and thickness of quartz veins encountered.

CUT-SLOPE STABILITY: Moderate; only fair if cleavage and joint surfaces dip into cut.

FOUNDATION STABILITY: Moderate to good; should be excavated to sound material.

CONSTRUCTION MATERIALS: Good source of fill where no embankments are involved.

HAMBURG SEQUENCE ROCKS (includes Oh, Ohsg, Ohg, and Ohl)

DESCRIPTION: Transported rocks of the Hamburg overthrust; gray, greenish-gray, and maroon shale, silty and siliceous in many places; dark-gray impure sandstone; medium- to light-gray, finely crystalline limestone and shaly limestone; total thickness is about 3,000 feet; reference section is along Nyes Road, Lower Paxton Township, Dauphin County.

BEDDING: Shale is moderately well bedded, thin; sandstone is well bedded, thick; limestone is well bedded, flaggy.

FRACTURING: Shale has a seamy to platy pattern; well developed; highly abundant; variable spacing; close distance between fractures; open and steeply dipping. Sandstone has a blocky pattern; well developed; moderately abundant; evenly spaced, having a moderate distance between fractures; open and vertical. Limestone has a platy pattern; poorly developed; moderately abundant; moderate distance between fractures; open and steeply dipping.

WEATHERING: Limestone is moderately resistant; moderately weathered to a shallow depth; small, flat, rectangular fragments result. Sandstone is moderately resistant; moderately weathered to a shallow depth; medium to large, irregularly shaped blocks result. Shale is moderately resistant; moderately to highly weathered to a deep depth; results in loose rubble of pencil-like fragments to rectangular plates; mantle is thin.

TOPOGRAPHY: Rolling valley of medium relief; natural slopes are moderate and stable.

DRAINAGE: Good surface drainage.

POROSITY AND PERMEABILITY: Joint- and bedding-plane openings provide a secondary porosity of moderate magnitude; locally solution openings in limestone produce a very high porosity and permeability.

GROUNDWATER: Yields of 10 to 50 gal/min are obtained from most wells; limestone may yield in excess of 100 gal/min; best location for high-yielding well is upland stream valley; water-bearing openings decrease in number and size with increased depth; most wells receive water from yielding zones less than 200 feet deep; surging and bailing with a commercial well conditioner is recommended.

EASE OF EXCAVATION: Moderately easy (shale) to difficult (sandstone and limestone); fast drilling rate.

CUT-SLOPE STABILITY: Fair, due to disintegration when exposed to moisture for a relatively short time.

FOUNDATION STABILITY: Good; should be excavated to sound material; an investigation for solution cavities should be made in areas underlain by limestone.

CONSTRUCTION MATERIALS: Good source of road material and fill.

HAMILTON GROUP (Dh)

DESCRIPTION: The Marcellus Formation and the overlying Mahantango Formation make up the Hamilton Group. Where this group is undifferentiated it is described as follows: the uppermost part consists of olive-gray to medium-olive-gray, fossiliferous siltstone and shale interbedded with fine-grained, medium-dark-gray sandstone; oolitic hematite occurs in a zone near the top; near the middle, light- to medium-gray, medium- to coarse-grained sandstone and several thin conglomerate beds occur. The base of the unit is characterized by medium- to dark-gray, fine-grained sandstone and dark-gray to black, fissile shale; maximum thickness is about 2,200 feet; reference sections are numerous—one along Sherman Creek between Falling Spring and Dromgold, Perry

County, and another in the railroad cut at South Altoona, Blair County, are outstanding.

BEDDING: Well bedded; shale is thin to fissile; sandstone is thin, flaggy, and medium bedded.

FRACTURING: Joints are well developed, closely spaced, mostly open, and steeply dipping; joints produce smooth, even-faced, sharp-edged rectangular blocks in sandstones.

WEATHERING: Moderately to poorly resistant; fissile shale weathers to light gray and disintegrates relatively easily into thin plates; sandstone weathers to light olive gray and yellowish brown and is moderately to highly resistant; overlying mantle is thin.

TOPOGRAPHY: Sandstone forms conspicuous ridges; shale underlies hills of medium height having stable slopes.

DRAINAGE: Good surface drainage.

POROSITY AND PERMEABILITY: Joint- and bedding-plane openings provide a secondary porosity of low to moderate magnitude; moderate permeability.

GROUNDWATER: Yields range from 1 to 300 gal/min; median yield is 30 gal/min; water may have high iron and sulfur content; hydrogen sulfide gas is common.

EASE OF EXCAVATION: Moderately easy to difficult; fast to moderate drilling rate.

CUT-SLOPE STABILITY: Good in sandstone; fair in shale.

FOUNDATION STABILITY: Good; should be excavated to fresh bedrock; may be need for underdrainage.

CONSTRUCTION MATERIALS: Good source of road material, riprap, building stone, and fill; shale may be a source of lightweight aggregate.

HAMMER CREEK FORMATION (Trh)

DESCRIPTION: Reddish-brown, coarse-grained sandstone having interbeds of red shale and quartz-pebble conglomerate; measured thickness at the type section is 9,360 feet; type section is along Hammer Creek, Lebanon County.

BEDDING: Well bedded; thick to massive.

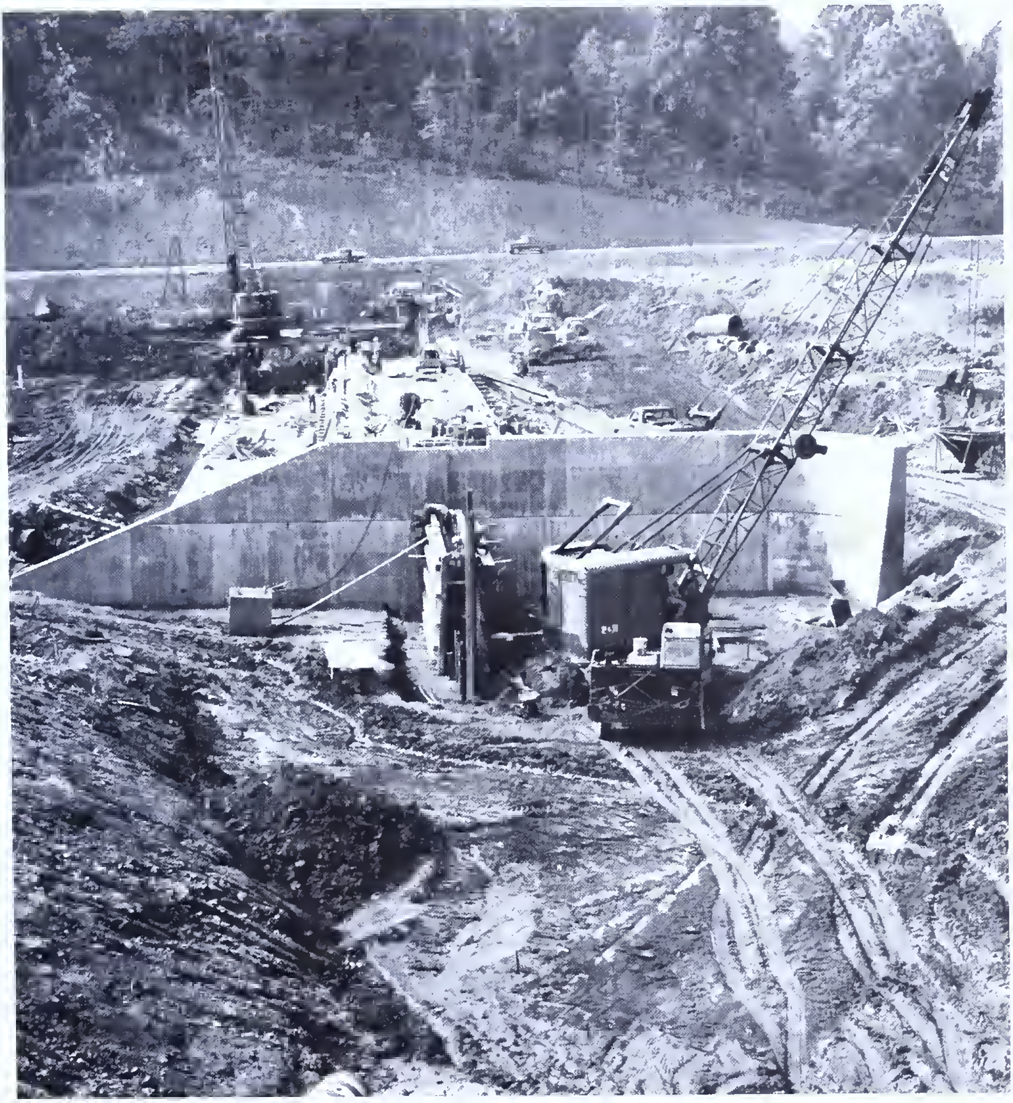
FRACTURING: Joints have a blocky pattern; moderately developed; moderately abundant; occur regularly; moderate distance between fractures; open and steeply dipping.

WEATHERING: Moderately resistant; shales are highly weathered to a moderate depth; sandstones weather less rapidly; conglomerates weather least rapidly; disintegration produces fragments ranging from large blocks to sand grains; overlying mantle is moderately thick.

TOPOGRAPHY: Rough terrain of high relief; natural slopes are steep and stable.

DRAINAGE: Good surface drainage.

POROSITY AND PERMEABILITY: Low primary porosity; moderate secondary porosity from joint- and bedding- plane openings; moderate to low permeability.



Dam construction in red sandstone, shale, and siltstone of the Hammer Creek Formation, Muddy Creek Waterfowl Preserve, State Game Lands No. 46.

GROUNDWATER: Median yield is 66 gal/min; hardness and total dissolved solids are frequently high.

EASE OF EXCAVATION: Difficult; slow drilling rate due to quartz-pebble conglomerate and in areas where rock is adjacent to diabase.

CUT-SLOPE STABILITY: Good to fair; landslides may occur where cut slopes are steep and rocks dip toward cut.

FOUNDATION STABILITY: Good; should be excavated to sound material.

CONSTRUCTION MATERIALS: Good source of road material and fill.

HAMMER CREEK FORMATION, CONGLOMERATE (Trhc)

DESCRIPTION: Very coarse quartz conglomerate; abundant pebbles and cobbles of gray quartzite; minor interbeds of coarse red sandstone; measured thickness is 2,580 feet; type section is along Hammer Creek in Lebanon County.

BEDDING: Thick to massive; well bedded.

FRACTURING: Joints have a blocky pattern; moderately developed; moderately abundant; occur regularly, having moderate distance between fractures; open and steeply dipping.

WEATHERING: Moderately resistant; disintegration ranges from large blocks to individual pebbles, cobbles, and sand grains; overlying mantle is thin.

TOPOGRAPHY: Rough terrain of high relief; natural slopes are steep and stable.

DRAINAGE: Good surface drainage.

POROSITY AND PERMEABILITY: Low primary porosity; low secondary porosity from joint- and bedding-plane openings; low permeability.

GROUNDWATER: Conglomerate beds are too discontinuous and interbedded with coarse red sandstone to be evaluated as a separate aquifer.

EASE OF EXCAVATION: Difficult; slow drilling rate due to quartz-pebble conglomerate.

CUT-SLOPE STABILITY: Good to fair; landslides may occur where cut slopes are steep and rocks dip toward cut.

FOUNDATION STABILITY: Good; should be excavated to sound material.

CONSTRUCTION MATERIALS: Good source of road material, fill, and riprap.

HARDYSTON FORMATION (€ha)

DESCRIPTION: Light-gray quartzite; weathers yellow brown; porous and limonitic in many places; quartz-pebble conglomerate occurs at base; maximum thickness is 800 feet; reference section is at Mt. Penn, Reading, Berks County.

BEDDING: Moderately well bedded to well bedded; thick.

FRACTURING: Joint and cleavage planes display a blocky pattern; moderately well developed; moderately abundant; widely spaced and fairly regular; steeply dipping and open.

WEATHERING: Highly resistant to weathering; usually slightly to moderately weathered to a shallow depth; hackly, large, irregularly shaped fragments result from weathering; locally, may be highly weathered to loose sand; overlying mantle is thin.

TOPOGRAPHY: Rough mountains of medium to high relief; natural slopes are steep and stable.

DRAINAGE: Good surface drainage.

POROSITY AND PERMEABILITY: Joint- and cleavage-plane openings produce a secondary porosity of low magnitude; low permeability.

GROUNDWATER: Median yield of 20 gal/min; water-yielding fractures are seldom found below 200 feet; water is usually soft and of good quality; iron may be a problem.

EASE OF EXCAVATION: Difficult; slow drilling rate, in part due to many quartz veins that exceed 12 inches in width; large boulders may be a special problem; locally highly fractured, highly weathered, and moderately easy to excavate.

CUT-SLOPE STABILITY: Good; locally, where highly fractured, cut-slope stability is fair.

FOUNDATION STABILITY: Good; should be excavated to sound material.

CONSTRUCTION MATERIALS: Good source of road material, riprap, building stone, and embankment facing; in some localities, provides material for refractory brick, and, where intensely fractured and weathered, sand.

ROCK TEST DATA:
Specific gravity (bulk) = 2.58
Compressive strength = 159 to 1,580 tons/ft^2

REMARKS: Specific-gravity data from USCE; other test data from Conwell and Company.

HARPERS FORMATION (Ꞓh; included in Ꞓah and Ꞓul)

DESCRIPTION: Dark-greenish gray phyllite and albite-mica schist; coarse-grained; abundant quartz; maximum thickness is about 1,500 feet; reference section is east of New Providence, Lancaster County.

BEDDING: Moderately well bedded; fissile.

FRACTURING: Joint and cleavage planes display a seamy pattern; moderately developed; highly abundant; irregularly distributed and very closely spaced; open and steeply dipping to moderately dipping.

WEATHERING: Moderately resistant; highly and deeply weathered; complete breakup of rock occurs in many places, resulting in medium- to small-sized fragments; overlying mantle is thin.

TOPOGRAPHY: Undulating hills of low relief; natural slopes are moderately steep and stable.

DRAINAGE: Good surface drainage.

POROSITY AND PERMEABILITY: Joint- and cleavage-plane openings provide a secondary porosity of low magnitude; low permeability.

GROUNDWATER: Median yield is 24 gal/min; yields are usually obtained from the fractured, weathered zone at the top of bedrock; water is mostly soft and of good quality; iron may be a problem.

EASE OF EXCAVATION: Weathered zone is moderately easy to excavate; unweathered rock is difficult; quartz boulders are a special problem; fast to moderate drilling rate.

CUT-SLOPE STABILITY: Fair; rapid disintegration when exposed to moisture for a relatively short time.

FOUNDATION STABILITY: Good; should be excavated to sound material.

CONSTRUCTION MATERIALS: Good source of road material and fill.

ROCK TEST DATA:
Permeability = 0 to 6 ft/day

REMARKS: Test data from SCS.

HARPERS FORMATION, MONTALTO MEMBER (Ꞓhm)

DESCRIPTION: Light-gray, vitreous quartzite; sometimes green to bluish gray; dark-gray phyllite at top; approximately 75 feet thick including 10+ feet of phyllite; reference section is along the Western Maryland railroad tracks west of the village of Iron Springs, Adams County.

BEDDING: Crudely bedded; thick to massive.

FRACTURING: Joints have an irregular pattern; poorly formed; highly abundant; moderately to closely spaced; steeply dipping and open.

WEATHERING: Moderately resistant; highly weathered to a deep depth; very small, irregularly shaped fragments result from weathering; overlying mantle is thin.

TOPOGRAPHY: Hills of medium relief; natural slopes are steep and stable.

DRAINAGE: Good surface drainage.

POROSITY AND PERMEABILITY: Joint openings provide a secondary porosity of low magnitude; low permeability.

GROUNDWATER: Yields are variable and range up to 20 gal/min; soft water; low iron and dissolved solids.

CUT-SLOPE STABILITY: Good; only fair where severely weathered.

FOUNDATION STABILITY: Good; should be excavated to sound material.

CONSTRUCTION MATERIALS: Good source of fill; sand and aggregate.

ROCK TEST DATA:
Shear data
  Phyllite-schist-quartzite
  Direct load at failure = 263 to 637 lb/in^2
  Maximum sliding resistance = 158 to 581 lb/in^2

REMARKS: Test data from USCE; specimens of NX core approximately 0.4 foot in length.

HARRELL FORMATION (included in Dbh)

DESCRIPTION: Gray to black, silty shale with thin argillaceous limestone, calcareous shale, and limestone nodules at the base; thickness is 100 to 200 feet; reference section is along east bank of Susquehanna River, north of U. S. Route 44 bridge, 1 mile northwest of Antes Fort, Lycoming County.

BEDDING: Well bedded; fissile to very thin; uniform in thick sequences.

FRACTURING: Highly developed, closely spaced, splintery fracturing within joint blocks set apart by widely spaced, steeply dipping fracture sets.

WEATHERING: Low to moderate resistance to weathering; shale-chip rubble accumulates on weathered surface; mantle is moderately thin.

TOPOGRAPHY: Forms low terrain of low relief and lower slopes of ridges capped by overlying Brallier and Trimmers Rock Formations; low to moderately steep natural slopes are stable.

DRAINAGE: Good surface drainage.

POROSITY AND PERMEABILITY: Joint- and bedding-plane openings provide low to moderate secondary porosity; permeability is low.

GROUNDWATER: Aquifer potential is low to moderate; reported yields range from 3 to 30 gal/min in wells 93 to 122 feet deep.

EASE OF EXCAVATION: Easy to moderately difficult in unweathered rock; may be excavated by ripper at right angle to bedding where rock is steeply dipping.

CUT-SLOPE STABILITY: Fair; considerable shale-chip rubble forms in exposed cuts; cuts parallel to bedding have poor stability.

FOUNDATION STABILITY: Good after excavation of weathered rock.

CONSTRUCTION MATERIALS: Good source of subgrade and light-duty road surfacing because of uniformity of material and relative ease of excavation.

HATTER FORMATION (included in Obl and Ocl)

DESCRIPTION: Medium-gray, silty and argillaceous limestone; laminated and dolomitic; contains oolites; maximum thickness is 200 feet; reference section is at Oak Hall, Centre County.

BEDDING: Well bedded; fissile to flaggy in most places; locally thick bedded.

FRACTURING: Joints have a blocky pattern; some have a platy pattern; moderately well developed; moderately to highly abundant; fairly regular, having a moderate distance between fractures; most fractures are open, but some are filled with calcite; steeply dipping to vertical.

WEATHERING: Moderately resistant; slightly weathered to a shallow depth; shaly limestone beds appear moderately weathered to a deeper depth; medium-sized blocks commonly result; overlying mantle is moderately thick; bedrock-mantle interface is pinnacled in most places.

TOPOGRAPHY: Rolling valley of low relief; natural slopes are gentle and stable.

DRAINAGE: Good subsurface drainage; poor surface drainage; sinkholes are common.

POROSITY AND PERMEABILITY: Joint and solution openings provide a secondary porosity of moderate to high magnitude; moderate to high permeability.

GROUNDWATER: Median yield is 50 gal/min; water quality is generally good, but easily contaminated; hardness is sometimes high.

EASE OF EXCAVATION: Difficult; bedrock pinnacles are a special problem; moderate drilling rate.

CUT-SLOPE STABILITY: Good; fair in shaly limestone beds that are susceptible to moisture and have a short-term stability; for steeply dipping beds inclined toward construction, stability is only fair.

FOUNDATION STABILITY: Good; should be excavated to sound material and should be thoroughly investigated for possible collapse areas.

CONSTRUCTION MATERIALS: Good source of fill.

ROCK TEST DATA:
Specific gravity = 2.67
Absorption = 0.50%

REMARKS: Test data from PDT.

HEIDLERSBURG MEMBER (SEE GETTYSBURG FORMATION)

HERSHEY FORMATION (included in Ohm and Oha)

DESCRIPTION: Dark-gray to black, argillaceous limestone; weathers medium gray to light brown; finely crystalline; basal conglomerate contains angular boulders of dolomite; maximum thickness may reach 1,000 feet in vicinity of reference section; thins westward; reference section is along U. S. Route 422, one mile east of Stouchsburg, Berks County.

BEDDING: Well bedded; thin to flaggy.

FRACTURING: Joints have a platy pattern; well developed; highly fractured; moderate distance between fractures; steeply dipping and open.

WEATHERING: Moderately resistant; moderately to highly weathered to a moderate depth; pencil-like, jagged fragments to medium size, elongate plates, and blocks result; overlying mantle is thin.

TOPOGRAPHY: Rolling valleys of low relief; natural slopes are gentle and stable.

DRAINAGE: Good surface and minor subsurface drainage.

POROSITY AND PERMEABILITY: Joint and solution openings provide a secondary porosity of low magnitude; low permeability.

GROUNDWATER: Median yield is 25 gal/min; low median yield shows that solution openings are not common.

EASE OF EXCAVATION: Moderately easy; difficult at depth where rock is unweathered; fast drilling rate.

CUT-SLOPE STABILITY: Fair, due to disintegration when exposed to moisture for a relatively short time.

FOUNDATION STABILITY: Good; should be excavated to sound material; should be investigated thoroughly for solution openings.

CONSTRUCTION MATERIALS: Good source of road material and fill.

HORNBLENDE GNEISS (hg)

DESCRIPTION: Dark-gray to black; most grains are about 1 to 2 mm in diameter; hornblende makes up about 50 percent of the rock; the other 50 percent is labradorite (feldspar); rock is extremely resistant to abrasion and very resistant to rupture, but may be susceptible to crumbling.

BEDDING: Banding is common; most bands are flaggy, but some are thick.

FRACTURING: Joints have a platy or blocky pattern; moderately to poorly formed; moderate to high in abundance; moderately to closely spaced; irregular; steeply dipping and open.

WEATHERING: Moderately resistant; highly and deeply weathered in many places, resulting in a rubble that contains small- to medium-sized rectangular fragments; overlying mantle is thin.

TOPOGRAPHY: Undulating hills of medium relief; natural slopes are moderately steep and stable.

DRAINAGE: Good surface drainage.

POROSITY AND PERMEABILITY: Extremely low primary porosity; joint openings provide a low secondary porosity; highly weathered near-surface rock may have high porosity; low permeability.

GROUNDWATER: Median yield of reported wells is 10 gal/min; yields of 35 gal/min or more may be obtained from wells properly sited and developed.

EASE OF EXCAVATION: Highly weathered portion of rock mass has moderately easy excavation; unweathered rock is difficult; fast to moderate drilling rate.

CUT-SLOPE STABILITY: Poor, due to partial disintegration when exposed to moisture for a relatively short time; drainage maintenance is required.

FOUNDATION STABILITY: Good; should be excavated to sound material.

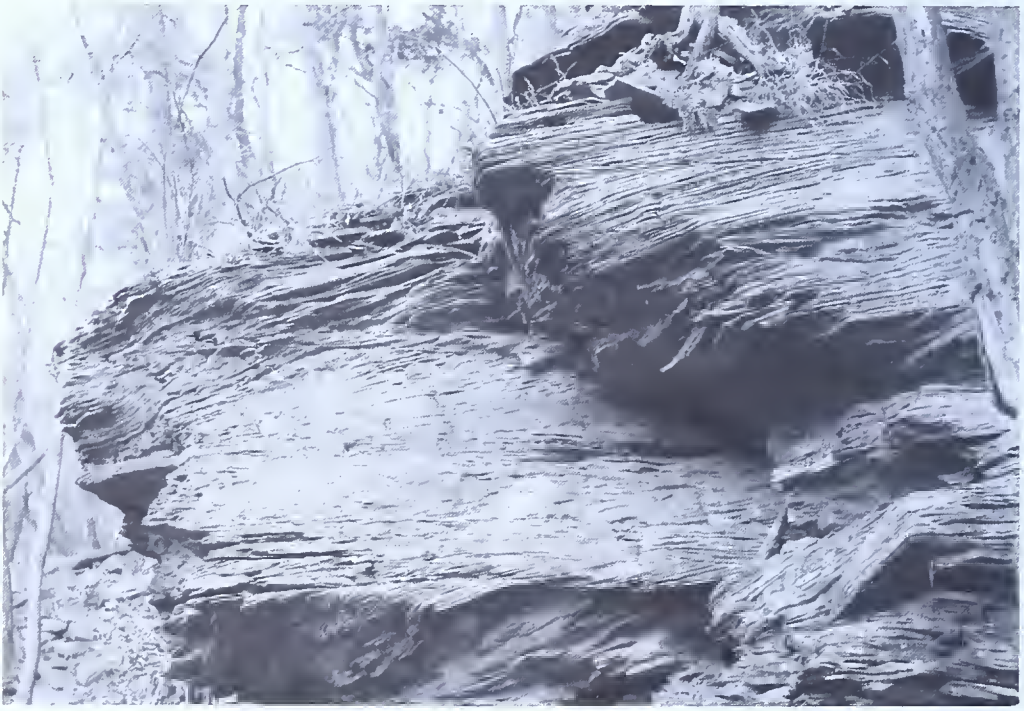
CONSTRUCTION MATERIALS: Good source of fill.

HUNTLEY MOUNTAIN FORMATION (MDhm)

DESCRIPTION: Composed of two sandstone sequences; upper unit is tan to olive, fine- to medium-grained, iron-stained, quartzitic sandstone having some shale and mudstone interbeds; lower unit is gray to tan, fine-grained, argillaceous sandstone containing some shale and mudstone interbeds; conglomerate up to 6 feet thick occurs in upper part; thickness is from 525 to 730 feet; reference section is along ridge crest northeast of Waterville, from elevation 1,050 to 1,550 feet, in Lycoming County.

BEDDING: Thin to medium; most beds are 3 to 6 inches thick; distinctive crossbedding.

FRACTURING: Well developed along steeply dipping joints and bedding-plane openings; joints are irregularly spaced from 2 inches to more than 2 feet; closely spaced bedding surfaces produce a laminated pattern.



WEATHERING: Moderately resistant; slightly weathered to a moderate depth; weathered surface is rough, and many overhangs occur in natural exposures; weathered fragments are tabular and range to more than 4 feet in diameter; mantle thickness is variable in talus, ranging from 1 foot to greater than 10 feet.

TOPOGRAPHY: Forms flanks of steep valley walls of incised plateau, having a topographic relief greater than 1,000 feet; natural slopes are steep and show evidence of past movement in unconsolidated mantle.

DRAINAGE: Good surface drainage.

POROSITY AND PERMEABILITY: Joint- and bedding-plane openings provide a moderate secondary porosity and moderate permeability.

GROUNDWATER: Average expected yield is 50 gal/min; water is generally of good quality with exception of possible high iron content.

EASE OF EXCAVATION: Difficult, but flaggy layers can be ripped near top of rock; moderate drilling rate.

CUT-SLOPE STABILITY: Good in fresh rock cuts; some rockfall; poor in overlying mantle, talus, and colluvium when steep natural slopes are disturbed.

FOUNDATION STABILITY: Excellent after excavation to sound material; poor in areas of steep slopes.

CONSTRUCTION MATERIALS: Good source of varicolored flagstone.

JACKSONBURG FORMATION (Ojk)

DESCRIPTION: Medium- to dark-gray limestone, coarsely crystalline; thin silty layers; fossiliferous; commonly called "cement limestone"; maximum thickness is 375 feet; reference section is in Alpha quarry no. 3 at Martins Creek, Northampton County; "cement rock" portion of formation is composed of silty limestone, dark-gray to black, fine-grained; thin pyrite seams; fossiliferous; 830 feet thick; reference section is at Mud Run, 2 miles southeast of Martins Creek, Northampton County.

BEDDING: Well bedded; thick to massive.

FRACTURING: Joints have a platy to angular blocky pattern; well developed; irregular distance between fractures; steeply dipping; open and calcite filled.

WEATHERING: Moderately resistant; moderately weathered to a moderate depth; irregularly shaped blocks to thin plates result; silty layers weather more rapidly than purer limestone, giving a ribbed appearance to outcrop; overlying mantle is thin.

TOPOGRAPHY: Rolling valleys of low relief; natural slopes are gentle and stable.

DRAINAGE: Good surface drainage; minor subsurface drainage.

POROSITY AND PERMEABILITY: Joint-, bedding-, and fault-plane openings provide a secondary porosity; low to moderate permeability and porosity.

GROUNDWATER: Median yield is 20 gal/min; water is hard.

EASE OF EXCAVATION: Difficult; moderately easy where severely weathered; moderate drilling rate.

CUT-SLOPE STABILITY: Moderate, due to differential weathering of silty limestone beds.

FOUNDATION STABILITY: Good; should be excavated to sound material; should be investigated for solution cavities.

CONSTRUCTION MATERIALS: Good source of fill.

ROCK TEST DATA:
Absorption = 0.21 to 0.42%
Specific gravity (bulk, saturated surface, dry) = 2.80 to 2.81
Compressive strength (shaly limestone to shale) = 53 to 97 tons/ft^2
Compressive strength (limestone) = 155 to 656 tons/ft^2

REMARKS: Compressive-strength test data from Conwell and Company; other test data from USCE.

JUNIATA FORMATION (Oj; included in Ojb)

DESCRIPTION: Brownish-red, fine-grained to conglomeratic, quartzitic sandstone having well-developed crossbedding; interbedded red shale; maximum thickness is 1,125 feet; reference section is along Interstate Route 80 at exit 27, Clinton County.

BEDDING: Well bedded; thin to flaggy.

FRACTURING: Joints have a blocky pattern; moderately developed; moderately fractured; regularly spaced, having a moderate distance between fractures; open and vertical.

WEATHERING: Highly resistant; slightly weathered to a shallow depth; results in medium- to large-sized blocks; overlying mantle is thin.

TOPOGRAPHY: Rough ridges of high relief; natural slopes are very steep and stable.

DRAINAGE: Good surface drainage.

POROSITY AND PERMEABILITY: Interstitial porosity is present, and a secondary porosity produced by joint-, fault-, and bedding-plane openings; mostly of low magnitude; low permeability.

GROUNDWATER: Median yield is 17 gal/min; generally is in a very poor topographic position for groundwater development; water quality is usually good.

EASE OF EXCAVATION: Difficult; slow drilling rate.

CUT-SLOPE STABILITY: Good.

FOUNDATION STABILITY: Good; should be excavated to sound material.

CONSTRUCTION MATERIALS: Good source of road material, riprap, and building stone.

KEEFER FORMATION (included in Sc and DSkc)

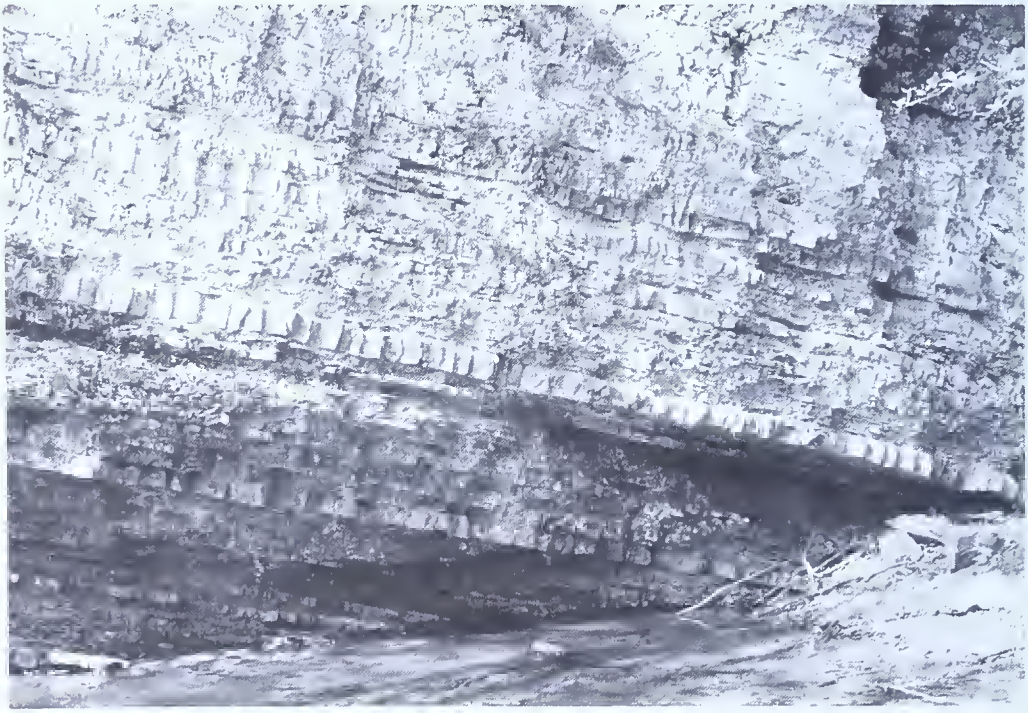
DESCRIPTION: Light-gray to yellowish-brown, very fine to coarse-grained, fossiliferous, siliceous sandstone, locally hematitic, locally conglomeratic; thickness is 24 to 55 feet; reference section is located onequarter mile north of borough of Mifflintown in roadcut on east side of old U. S. Route 22, Juniata County.

BEDDING: Well bedded; thin to thick; crossbedded.

FRACTURING: Well developed, having moderate to wide spacing in a blocky and tabular pattern; joints are generally open and narrow; some are filled with calcite.

WEATHERING: Moderately weathered to a shallow depth; mantle is thin and in many places bouldery, containing fragments 1 inch to 5 feet in diameter; weathered surface is rough.

TOPOGRAPHY: Supports a distinct ridge along lower flanks of higher ridges in Valley and Ridge province, forming hills of low to moderate relief; natural slopes are moderate to steep and stable.



DRAINAGE: Good surface drainage.

POROSITY AND PERMEABILITY: Thin zones of moderate to low primary porosity; secondary porosity in joint- and bedding-plane openings; moderately permeable.

GROUNDWATER: Potential yield is low, estimated to range from 5 to 15 gal/min in wells up to 200 feet deep; quality is good.

EASE OF EXCAVATION: Moderately difficult; moderate drilling rate.

CUT-SLOPE STABILITY: Good; some rockfall is to be expected from steep cuts; poor stability in cuts made parallel to bedding.

FOUNDATION STABILITY: Good after removal of weathered mantle.

CONSTRUCTION MATERIALS: Good source of rock fill, riprap, and rock protection.

KEYSER FORMATION (included in DSkt, DSkm, and DSkc)

DESCRIPTION: Dark-gray, highly fossiliferous, crystalline to nodular limestone; shaly limestone near top; 270 to 290 feet thick; reference section is along road, 0.25 mile south of the village of Pine Grove, Perry County.

BEDDING: Well bedded; flaggy to thick; some beds are massive.

FRACTURING: Joints have a platy pattern; some have a blocky pattern; moderately developed; moderately to highly abundant; regularly spaced, having a moderate to close distance between fractures; open and steeply dipping.

WEATHERING: Moderately resistant; moderately weathered to a moderate to shallow depth; results in small- to medium-sized, irregularly shaped blocks; mantle is usually thin; bedrock pinnacles may exist.

TOPOGRAPHY: Rolling hills of medium relief; natural slopes are moderate and stable.

DRAINAGE: Good surface drainage; minor subsurface drainage.

POROSITY AND PERMEABILITY: Solution channels and joint- and bedding-plane openings provide a secondary porosity of moderate magnitude; low to moderate permeability.

GROUNDWATER: Median yield is 30 gal/min; solution cavities may be encountered; water quality decreases with increasing depth; water is frequently hard; some iron problems.

EASE OF EXCAVATION: Difficult; bedrock pinnacles are a special problem; fast drilling rate.

CUT-SLOPE STABILITY: Good; where rock is intensely fractured, only fair.

FOUNDATION STABILITY: Good; thorough investigation for solution openings should be undertaken; should be excavated to sound material.

CONSTRUCTION MATERIALS: Good source of road material, riprap, embankment facing, and fill.

ROCK TEST DATA:
Specific gravity = 2.65 to 2.80
Absorption = 0.20 to 0.96%

REMARKS: Test data from PDT.

KINZERS FORMATION, SHALE (included in Ꞓk and Ꞓul)

DESCRIPTION: Dark-brown shale; contains the trilobite *Olenellus*; 150 feet thick; type section is in Pennsylvania Railroad cut at Kinzers, Lancaster County.

BEDDING: Moderately well bedded; fissile.

FRACTURING: Joint and cleavage planes display a seamy pattern; moderately developed; highly abundant; irregularly distributed and very closely spaced; open and steeply dipping to moderately dipping.

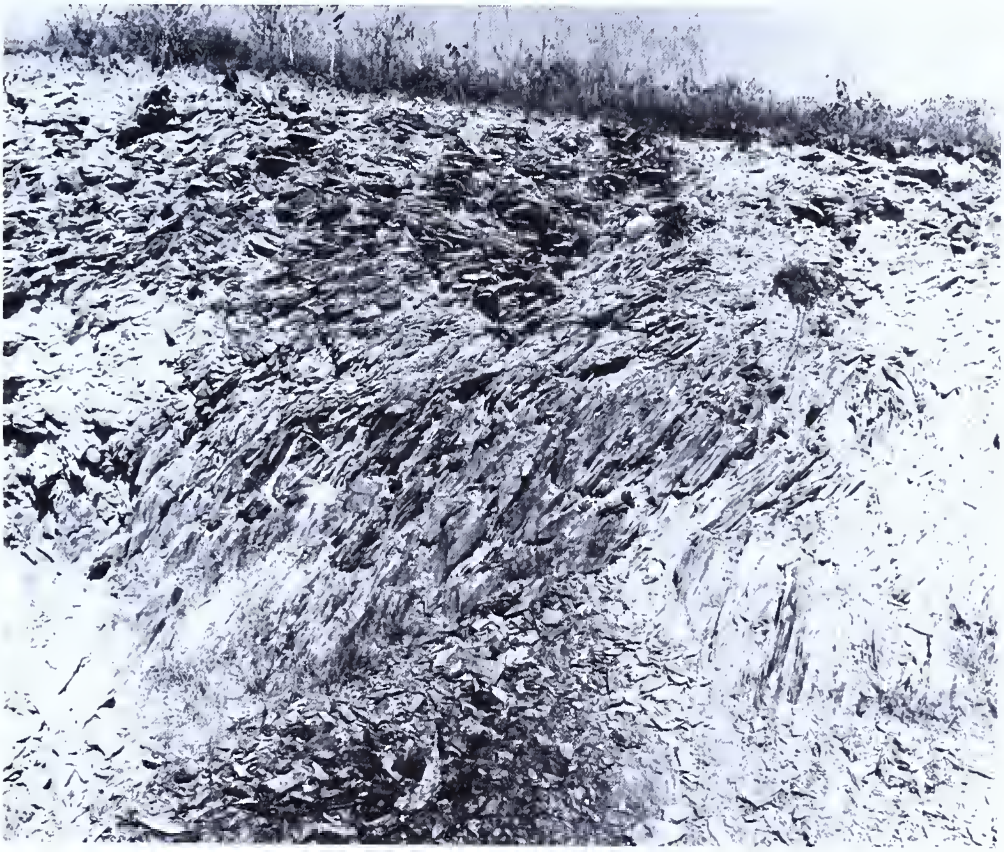
WEATHERING: Moderately resistant; highly and deeply weathered; complete breakup of rock occurs in many places, resulting in medium- to small-sized fragments; overlying mantle is thin.

TOPOGRAPHY: Undulating hills of low relief; natural slopes are moderately steep and stable.

DRAINAGE: Good surface drainage.

POROSITY AND PERMEABILITY: Joint- and cleavage-plane openings provide a secondary porosity of moderate magnitude; moderate permeability.

GROUNDWATER: Median yield is 30 gal/min; well yields range from less than 1 to 400 gal/min.



EASE OF EXCAVATION: Moderately easy; unweathered rock is difficult; quartz boulders are a special problem; moderate drilling rate.

CUT-SLOPE STABILITY: Fair; rapid disintegration when exposed to moisture for a relatively short time.

FOUNDATION STABILITY: Good; should be excavated to sound material.

CONSTRUCTION MATERIALS: Good source of road material and fill.

ROCK TEST DATA:
Specific gravity = 2.66 to 2.81
Absorption = 0.26 to 0.64%

REMARKS: Test data from PDT.

LARKE FORMATION (included in Osl and Ons)

DESCRIPTION: Coarsely crystalline, dark-gray dolomite; includes thick layers of fossiliferous limestone near middle of formation; lower part is light-gray, fine-grained, laminated dolomite; sand grains in the thin laminae weather slower than surrounding dolomite, resulting in fine, raised lines on weathered surfaces; about 250 feet thick; type section is at Larke, Blair County.

BEDDING: Well bedded; thick; lower 50 feet of formation is thin bedded.

FRACTURING: Joints have a blocky pattern; moderately well developed; moderately abundant; regularly spaced at moderate intervals; open and nearly vertical.

WEATHERING: Moderately resistant; slightly to moderately weathered to a shallow depth; small- to medium-sized blocks form the talus; soil-bedrock interface is pinnacled.

TOPOGRAPHY: Rolling valley of low relief; natural slopes are gentle and stable.

DRAINAGE: Good subsurface drainage; little surface drainage.

POROSITY AND PERMEABILITY: Joint and solution openings provide a secondary porosity of moderate to high magnitude; highly permeable.

GROUNDWATER: Median yield is greater than 100 gal/min.

EASE OF EXCAVATION: Difficult; bedrock pinnacles are a special problem; fast drilling rate.

CUT-SLOPE STABILITY: Good; where limestone underlies dolomite in a rock face and the limestone weathers more rapidly, rockfalls may occur.

FOUNDATION STABILITY: Good; thorough investigation for solution openings should be undertaken.

CONSTRUCTION MATERIALS: Good source of road material, riprap, embankment facing, and fill.

LEDGER FORMATION (Єl; included in Єul)

DESCRIPTION: Light-gray, locally mottled, massive, pure, coarsely crystalline dolomite; siliceous in middle part; beds weather to rust-stained, granular, cherty layers; approximately 2,000 feet thick; type section is at Ledger, Lancaster County.

BEDDING: Moderately well bedded; massive.

FRACTURING: Joints have a blocky pattern; moderately to well developed; moderately abundant; irregularly spaced, having a wide distance between fractures; open and steeply dipping.

WEATHERING: Moderately resistant; slightly to moderately weathered to a shallow depth; breakup results in large blocks; overlying mantle is thin; pinnacles characterize the interface between mantle and bedrock.

TOPOGRAPHY: Low relief; natural slopes are gentle and steep.

DRAINAGE: Good surface and subsurface drainage.

POROSITY AND PERMEABILITY: Joint- and bedding-plane openings and solution channels provide secondary porosity of low to high magnitude; low to high permeability.

GROUNDWATER: Median yield is 30 gal/min; well yields range from less than 1 to 400 gal/min; 82 percent of wells tested had yields greater than 25 gal/min.

Embankment facing, Ledger Formation.

EASE OF EXCAVATION: Difficult; bedrock pinnacles are a special problem; fast drilling rate.

CUT-SLOPE STABILITY: Good.

FOUNDATION STABILITY: Good; solution openings and bedrock pinnacles should be thoroughly investigated.

CONSTRUCTION MATERIALS: Good source of road material, riprap, concrete aggregate, building stone, embankment facing, and fill.

ROCK TEST DATA:
Specific gravity = 2.72 to 2.82
Absorption = 0.22 to 0.70%

REMARKS: Test data from PDT.

LEITHSVILLE FORMATION (Ꞓlv)

DESCRIPTION: Dark-gray to medium-gray dolomite; some calcareous shale and sandy dolomite; cherty; 1,500 feet thick; type section is at Leithsville, Northampton County.

BEDDING: Moderately well bedded; massive.

FRACTURING: Joints have a blocky pattern and are moderately to well developed; moderately abundant; irregularly spaced, having a wide distance between fractures; open and steeply dipping.

WEATHERING: Moderately resistant; slightly to moderately weathered to a shallow depth; breakup results in large blocks; overlying mantle is thin and pinnacles may characterize the interface between mantle and bedrock.

TOPOGRAPHY: Undulating valley of low to medium relief; natural slopes are gentle to moderately steep and stable.

DRAINAGE: Good surface drainage; little subsurface drainage.

POROSITY AND PERMEABILITY: Joint openings and solution channels provide a secondary porosity of high magnitude; moderate to high permeability.

GROUNDWATER: Median yield is 100 gal/min; large yields may be obtained from solution openings; aquifer can be easily contaminated; turbidity is a common water-quality problem; water is relatively hard.

EASE OF EXCAVATION: Difficult; bedrock pinnacles may be a special problem; fast drilling rate.

CUT-SLOPE STABILITY: Good.

FOUNDATION STABILITY: Good; solution openings and bedrock pinnacles should be thoroughly investigated.

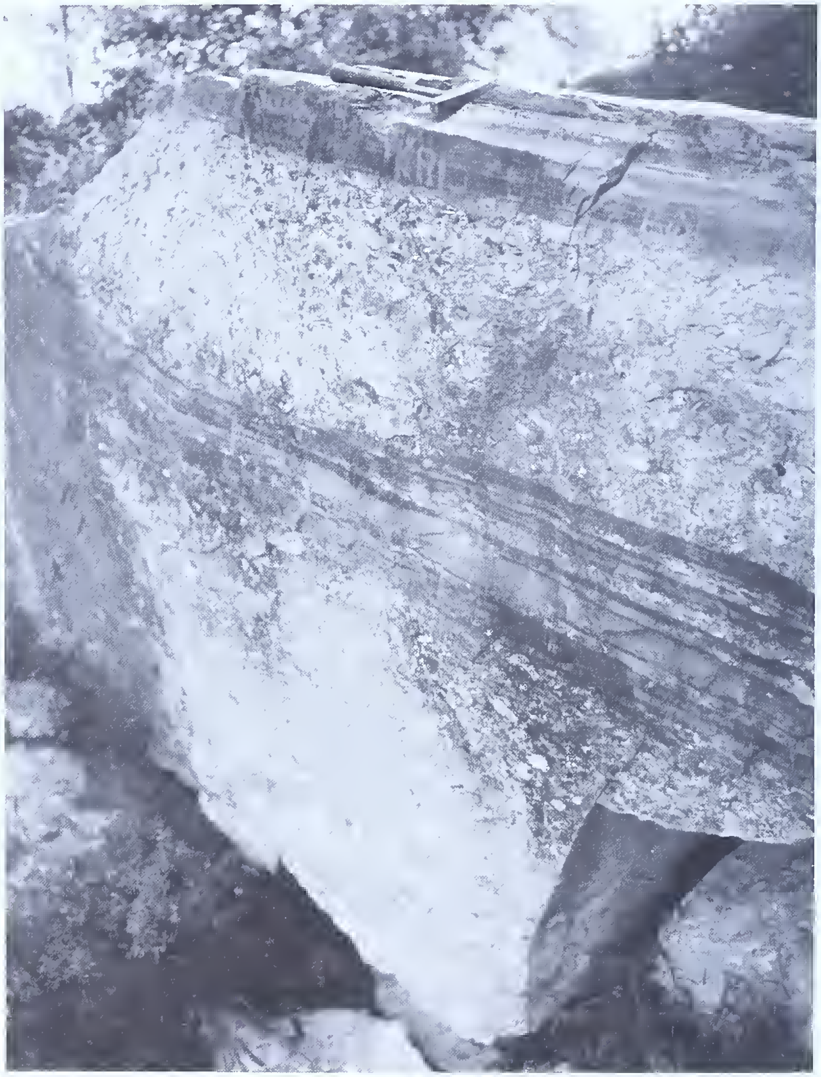
CONSTRUCTION MATERIALS: Good source of road material, riprap, concrete aggregate, building stone, embankment facing, and fill.

LIMESTONE FANGLOMERATE (Trfl)

DESCRIPTION: Fanglomerate composed chiefly of limestone and dolomite pebbles and fragments; fragments are angular and up to 8 inches in diameter; fragments and pebbles are mostly yellow gray to light medium gray; a few shale fanglomerate interbeds; very fine grained, red quartz matrix; approximately 200 feet thick; reference section is in quarry one-half mile south of Fairfield, Adams County.

BEDDING: Moderately well bedded; thick.

FRACTURING: Joints have an irregular pattern; poorly formed; moderately spaced; steeply dipping and open.



WEATHERING: Moderately resistant; moderately weathered to a shallow depth; results in medium-sized triangular blocks; limestone and dolomite are completely dissolved in places, leaving an uneven hole in the rock; mantle is moderately thick.

TOPOGRAPHY: Undulating hills of medium relief; natural slopes are moderately steep and stable.

DRAINAGE: Good surface drainage.

POROSITY AND PERMEABILITY: Joint and solution openings provide a moderate secondary porosity; moderate to high permeability.

GROUNDWATER: Median yield is in excess of 200 gal/min for nondomestic wells; yields in excess of 800 gal/min have been reported.

EASE OF EXCAVATION: Difficult; fast drilling rate.

CUT-SLOPE STABILITY: Good.

FOUNDATION STABILITY: Good; sinkholes have been observed, and detailed investigation should be undertaken.

CONSTRUCTION MATERIALS: Good source of decorative stone and fill.

LINDEN HALL FORMATION (SEE BENNER FORMATION)

LLEWELLYN FORMATION (ℙl)

DESCRIPTION: Interbedded sandstone, siltstone, and conglomerate; medium to coarse grained; light gray to brown; contains coal and dark-gray to black shales; a maximum thickness of 830 feet has been reported; reference section is along Interstate Route 81 at mile 107, Schuylkill County.

BEDDING: Moderately well developed; coal and shale are thin; sandstone, siltstone, and conglomerate may be thick to massive.

FRACTURING: Joints are moderately developed; moderately abundant; blocky pattern; moderately spaced; regular sequence; open and steeply dipping.

WEATHERING: Slightly to moderately weathered; shallow to moderate depth; depending on lithology, rubble consists of small to medium, flat, elongate fragments to large blocky fragments; overlying mantle is thin to moderate.

TOPOGRAPHY: Low ridges and valleys in rolling terrain; natural slopes are stable at moderate angles.

DRAINAGE: Good surface drainage.

POROSITY AND PERMEABILITY: Total effective porosity is moderate; moderate to low permeability.

GROUNDWATER: Average yield is 38 gal/min; high iron and acidity are common quality problems.

EASE OF EXCAVATION: Difficult; fast to slow drilling rate, depending on lithology.

CUT-SLOPE STABILITY: Fair to good; undercutting of shale and siltstone under more resistant sandstone and conglomerate units can be a severe problem; support-drainage maintenance may be required to reduce weathering from excessive moisture.

FOUNDATION STABILITY: Good; should be excavated to sound material; extreme caution should be exercised where coals have been removed underground.

CONSTRUCTION MATERIALS: Good source of road material and fill; conglomerate is suitable for building stone, flagstone, embankment facing, and riprap.

LOCKATONG FORMATION (Trl)

DESCRIPTION: Dark-gray to black argillite having some zones of black shale; locally, thin layers of impure calcareous shale; maximum thickness is approximately 3,800 feet; reference section is along Delaware River between Point Pleasant and Lumberville, Bucks County.

BEDDING: Moderately well developed; flaggy to thick.

FRACTURING: Joints have a blocky pattern; moderately developed; closely spaced; steeply dipping and open.

WEATHERING: Moderately resistant; moderately weathered to a shallow depth; small elongate and triangular fragments result from rapid hydration of minerals in exposed rock; overlying mantle is moderately thick.

TOPOGRAPHY: Rolling hills of medium relief; natural slopes are moderately steep and stable.

DRAINAGE: Good surface drainage.

POROSITY AND PERMEABILITY: Joint openings provide a secondary porosity; both weathered and unweathered rock have a low porosity; low permeability.

GROUNDWATER: Average yield is 35 gal/min; lithology is an important factor in well yield.

EASE OF EXCAVATION: Upper few feet may be excavated moderately easily; unweathered bedrock is difficult; slow to moderate drilling rate.

CUT-SLOPE STABILITY: Good.

FOUNDATION STABILITY: Good; should be excavated to sound material; may need grouting for extremely heavy loads.

CONSTRUCTION MATERIALS: Good source of fill.

LOCK HAVEN FORMATION (Dlh)

DESCRIPTION: Interbedded light-olive-gray, very fine grained, fossiliferous sandstone, light-gray siltstone, and gray silty shale; locally hematitic; contains angular shale pebbles; a few conglomerate beds occur near top; ''Chemung'' of earlier workers; approximately 4,000 feet thick; reference section is along the east side of Pa. Route 44 at Torbert, Lycoming County.

BEDDING: Sandstone is thin and medium bedded; crossbedded in some places; lenticular in many places; siltstone is very thin to medium bedded; shale is thin to very thick bedded.

FRACTURING: Joints are poorly to well developed and have a moderate to wide spacing; nearly vertical; open.

WEATHERING: Moderately resistant; weathered to a shallow depth; mantle is thin to moderately thick.

TOPOGRAPHY: Forms hills and ridges of moderate relief; fairly steep to steep natural slopes; slopes are stable.

DRAINAGE: Good surface drainage.

POROSITY AND PERMEABILITY: Joint- and bedding-plane openings provide a secondary porosity of low magnitude; low permeability.

GROUNDWATER: Reported yields range from 2 to over 300 gal/min; water-quality problems include brackish water and hydrogen sulfide.

EASE OF EXCAVATION: Moderately difficult; highly fractured shale near surface is easily excavated.

CUT-SLOPE STABILITY: Fair to good; sandstone, siltstone, and conglomerate have good stability; shale breaks down rapidly and has only fair stability.

FOUNDATION STABILITY: Good; should be excavated to sound bedrock.

CONSTRUCTION MATERIALS: Good source of road material and random fill.

ROCK TEST DATA:

Sandstone containing shale seams, beds, or nodules
- Water content = 0.4 to 1.0%
- Dry density = 158 to 166 lb/ft^3
- Modulus of rupture = 84.1 to 1,625.0 lb/in^2
- Sliding resistance = 4.8 to 91.0 lb/in^2 after shear

Siltstone (specimens of a 6-inch-diameter core)
- Unconfined compression (unit load at failure) = 6,865 to 7,712 lb/in^2
- Modulus of elasticity = 1.647×10^6 to 2.416×10^6 lb/in^2
- Shear data
  - Direct unit load = 952 to 1,184 lb/in^2 at failure

Clay shale
- Field water content = 1.7%
- Shear data
  - Direct unit load = 49 to 493 lb/in^2 at failure

Calcareous, silty shale (2-inch-diameter specimens cored from 4-inch-diameter core)
- Unconfined compression (unit load at failure) = 10,920 lb/in^2
- Modulus of elasticity = 1.0 to 1.19×10^6 lb/in^2
- Field water content = 0.6 to 1.6%
- Shear data
  - Direct unit load = 243 to 762 lb/in^2 at failure
  - Maximum sliding resistance = 224 to 454 lb/in^2

Shaly siltstone (2-inch-diameter specimens cored from 4-inch-diameter core)
- Unconfined compression (unit load at failure) = 3,554 to 6,676
- Modulus of elasticity = 0.65 to 1.25×10^6 lb/in^2
- Field water content = 0.4 to 1.1%

REMARKS: Test data from USCE.

LOUDOUN FORMATION (included in Ꞓwl)

DESCRIPTION: Dark-gray, dusky-blue, and very dusky red purple phyllite interbedded with fine-grained sandstone; phyllite may contain elongated, ivory-colored spots; contains conglomerate with gray quartz pebbles and pinkish-gray granite fragments, surrounded by a gray to greenish, micaceous to sandy matrix; maximum thickness is about 150 feet; reference area is the summit of Haycock, Adams County.

BEDDING: Well bedded; thick.

FRACTURING: Moderately well jointed at moderate to wide spacing; open; well-developed cleavage in phyllite intervals; very closely spaced; inclined at moderate to steep angle.

WEATHERING: Moderately resistant; phyllite is commonly highly and deeply weathered; overlying mantle is thin to moderate.

TOPOGRAPHY: Lower slopes of ridges in the South Mountain region of Pennsylvania.

DRAINAGE: Good surface drainage.

POROSITY AND PERMEABILITY: Joint- and cleavage-plane openings provide a secondary porosity of low magnitude; low permeability.

GROUNDWATER: Average yield of wells is 6 to 7 gal/min; about half of all wells drilled yield 3 gal/min or less; necessary well depth for adequate domestic supply is 50 to 100 feet; fracture zones, stream valleys, and fault zones are the best potential well sites; good quality; water is soft and of low mineral content.

EASE OF EXCAVATION: Difficult except for phyllite intervals and highly fractured rock.

CUT-SLOPE STABILITY: Fair; phyllite forms gentle to moderate slopes where cleavage dips into cut.

FOUNDATION STABILITY: Good; should be excavated to solid rock.

CONSTRUCTION MATERIALS: Good source of fill.

LOYSBURG FORMATION (included in Obl and Ocl)

DESCRIPTION: Light- to medium-gray, shaly limestone (Clover Member) and laminated, alternating medium-gray limestone, dolomitic limestone, and dolomite (Milroy Member); latter unit is often referred to as the "tiger striped" member; approximately 150 feet thick; type section is at Loysburg, Bedford County.

BEDDING: Well bedded; thick.

FRACTURING: Joints have a blocky pattern; platy pattern appears in some places; moderately well developed; moderately to highly abundant; fairly regular, having a moderate distance between fractures; most fractures are open, but some are filled with calcite; steeply dipping to vertical.

WEATHERING: Moderately resistant; slightly weathered to a shallow depth; medium-sized blocks commonly result; overlying mantle is moderately thick; the bedrock-mantle interface is characterized by pinnacles in most places.

TOPOGRAPHY: Rolling valley of low relief; natural slopes are gentle and stable.

DRAINAGE: Good subsurface drainage; poor surface drainage; sinkholes are common.

POROSITY AND PERMEABILITY: Joint and solution openings provide a secondary porosity of moderate to high magnitude; moderate permeability.

GROUNDWATER: Median yield is 50 gal/min; water quality is generally good, but easily contaminated; hardness is sometimes high.

EASE OF EXCAVATION: Difficult; bedrock pinnacles are a special problem; moderate drilling rate.

CUT-SLOPE STABILITY: Good; where steeply dipping beds are inclined toward the roadway, stability is only fair.

FOUNDATION STABILITY: Good; should be excavated to sound material and should involve a thorough investigation for possible collapse areas.

CONSTRUCTION MATERIALS: Good source of road material and fill.

ROCK TEST DATA:
Specific gravity = 2.67
Absorption = 0.50%

REMARKS: Test data from PDT.

MAFIC GNEISS, HORNBLENDE-BEARING; MAFIC GNEISS, PYROXENE-BEARING (SEE GABBROIC GNEISS)

MAHANTANGO FORMATION (Dmh; included in Dh)

DESCRIPTION: Medium-gray, olive-weathering, fine- to coarse-grained sandstone and numerous dark-gray to brown shale interbeds; includes "Centerfield coral reef" in eastern Pennsylvania; also includes the following members, in descending order: Tully Limestone, Sherman Ridge Sandstone, Montebello Sandstone, Fisher Ridge Sandstone, Dalmatia Shale, and Turkey Ridge Sandstone; in south-central Pennsylvania, includes Clearville, Frame, Chaneysville, and Gander Run Members; maximum thickness is approximately 1,100 feet; type section is along North Branch of Mahantango Creek, Juniata County.

BEDDING: Well developed; thin to flaggy.

FRACTURING: Joints are closely spaced; well developed; blocky pattern; open and steeply dipping.

WEATHERING: Moderately to poorly resistant; disintegrates relatively easily into small pieces of blocky, irregularly shaped talus.

TOPOGRAPHY: Rolling hills of medium relief having stable slopes; steepness varies from gentle to steep.

DRAINAGE: Good surface drainage.

POROSITY AND PERMEABILITY: Joint- and bedding-plane openings provide a secondary porosity of moderate to low magnitude; low permeability.

GROUNDWATER: Median yield is 20 gal/min; high iron and hydrogen sulfide are common; water often leaves white sulfur-like deposits.

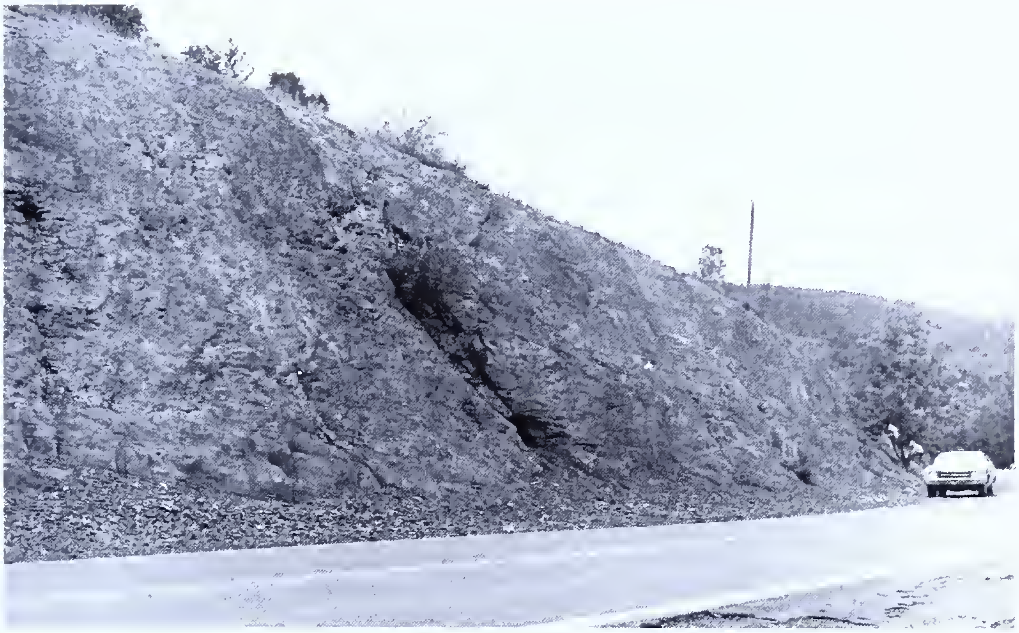
EASE OF EXCAVATION: Moderately easy to moderately difficult; locally difficult; fast to moderate drilling rate.

CUT-SLOPE STABILITY: Fair, due to rapid weathering along closely spaced joints; cuts in the "Centerfield coral reef" are stable at fairly steep angles.

FOUNDATION STABILITY: Good; need for excavation to sound material; need for underdrainage.

CONSTRUCTION MATERIALS: Good source of road material and fill and potential source of lightweight aggregate.

ROCK TEST DATA:
Permeability = 0 to 50 ft/day; rates are highly variable
Water of plasticity = 16 to 21%
Drying shrinkage = 0.5 to 4.0%
P-wave velocity (fresh bedrock) = 13,000 to 16,000 ft/sec
P-wave velocity (weathered rock) = 3,000 to 4,000 ft/sec



Mahantango Formation, "Centerfield coral reef."

REMARKS: Permeability data from SCS; other data from USBM.

MAHANTANGO FORMATION, MONTEBELLO SANDSTONE (included in Dmh and Dh)

DESCRIPTION: Medium-grained, light- to olive-gray, hard, tough sandstone; highly fossiliferous in some areas; interbedded dark-medium-gray to olive shale and siltstone; average thickness of unit in Perry County is 1,000 feet; reference section is at Sherman Ridge, Perry County.

BEDDING: Moderate to well bedded and thick.

FRACTURING: Joints are well developed in a blocky pattern; moderately to highly fractured; regularly spaced, having moderate distance between fractures; open and steeply dipping.

WEATHERING: Highly resistant; slightly weathered to a shallow depth; overlying mantle is thin.

TOPOGRAPHY: Forms rolling ridges and hogbacks; natural slopes are stable and moderate to steep.

DRAINAGE: Good surface drainage.

POROSITY AND PERMEABILITY: Joint openings provide a secondary porosity of low to moderate magnitude; low permeability.

GROUNDWATER: Median yield is 30 gal/min; sandstone yields slightly more than shale; may be a poor aquifer due to topographic position.

EASE OF EXCAVATION: Difficult; drilling rate is moderate to slow.

CUT-SLOPE STABILITY: Good.

FOUNDATION STABILITY: Good; should be excavated to sound bedrock.

CONSTRUCTION MATERIALS: Good source of road material, riprap, building stone, and fill.

MARCELLUS FORMATION (Dm; included in Dh)

DESCRIPTION: Black, carbonaceous shale; limestone (Purcell Member) occurs locally; may contain abundant pyrite and siderite concretions and nodules; Tioga bentonite is included at base in eastern Pennsylvania; approximate maximum thickness is 350 feet; reference section is at Susquehanna Gap, Dauphin County.

BEDDING: Moderately well to well bedded; fissile.

FRACTURING: Joints have a platy pattern; poorly formed; moderately abundant; closely spaced; many are open but a few are closed and filled; steeply dipping.

WEATHERING: Slightly to moderately resistant; moderately to highly weathered to a moderate depth; results in small, flaggy, pencil-like fragments at base of exposure; overlying mantle is thin.

TOPOGRAPHY: Undulating hills of medium relief; natural slopes are fairly steep and stable.

DRAINAGE: Good surface drainage.

POROSITY AND PERMEABILITY: Joint-, fault-, and bedding-plane openings provide a secondary porosity of low magnitude; low permeability.

GROUNDWATER: Median yield is 20 gal/min; high iron and hydrogen sulfide are common.

EASE OF EXCAVATION: Moderately easy; fast drilling rate.

CUT-SLOPE STABILITY: Fair, due to disintegration when exposed to moisture for a short time.

FOUNDATION STABILITY: Good; should be excavated to sound material.

CONSTRUCTION MATERIALS: Good source of road material and fill; possible source of lightweight aggregate.

ROCK TEST DATA:
Permeability = 0 to 25 ft/day
Water of plasticity = 17 to 22%

Drying shrinkage = 0.5 to 1%
Strength test data:
  Shale, dark-gray to black, carbonaceous
    Direct unit load at failure = 195 to 670 lb/in^2
    Maximum sliding resistance (sheared rock surface) = 144 to 594 lb/in^2
    Maximum sliding resistance (smooth rock surface) = 9 to 97 lb/in^2
    Compression (unit load at failure) = 3,533 lb/in^2
Physical properties:
  Field water content = 1.6 to 1.8%
  Unit dry weight = 165.4 to 166.3 lb/ft^3

REMARKS: Permeability data from SCS; water of plasticity and drying shrinkage data from USBM; strength test data from USCE on selected 6-inch-diameter core.

MARTINSBURG FORMATION (includes Om, Omgs, and Oml)

DESCRIPTION: Buff-weathering, dark-gray shale, and thin interbeds of siltstone, metabentonite, and fine-grained sandstone; brown-weathering, medium-grained sandstone containing shale and siltstone interbeds occurs in the middle of the formation; basal part grades into limy shale and platy-weathering, silty limestone; may be 12,800 feet thick; reference section is in a small quarry along Longs Gap Road, North Middleton Township, Cumberland County.

BEDDING: Well bedded; sandstone is thick to massive; limestone and shale are thin to fissile.

FRACTURING: Cleavage is dominant and highly developed; joints are also present, and are irregularly spaced, open, and nearly vertical.

WEATHERING: Moderately weathered to a moderate depth; small to large platy fragments result; mantle is thick.

TOPOGRAPHY: Dissected valley of low relief; natural slopes along streams are steep and often unstable.

DRAINAGE: Good surface drainage.

POROSITY AND PERMEABILITY: Cleavage- and joint-plane openings provide a secondary porosity of generally low magnitude; low permeability.

GROUNDWATER: A median sustained yield of 32 gal/min has been calculated and a maximum well yield of 200 gal/min is reported; yielding zones are commonly less than 150 feet in depth but occur as deep as 400 feet below land surface; the natural quality of the water is often poor due to hydrogen sulfide and high concentrations of iron.

EASE OF EXCAVATION: Moderately easy in shale; moderately difficult in limestone; difficult in sandstone; fast drilling rate.

CUT-SLOPE STABILITY: Fair in shale and limestone; good in sandstone.

FOUNDATION STABILITY: Good; should be excavated to sound rock; limestone should be investigated for solution openings.

CONSTRUCTION MATERIALS: Good source of road material and fill.

MAUCH CHUNK FORMATION (Mmc)

DESCRIPTION: Dominant rock types are shale, claystone, sandstone, and siltstone; sandstone is fine to medium grained and crossbedded; shale and claystone are red; sandstone and siltstone are usually gray, green, and greenish gray; maximum thickness is 3,000 feet; type section is at Mauch Chunk, Carbon County.

BEDDING: Moderately well bedded, thin, and flaggy; crossbedding is common in sandstone and siltstone; ripple marks and rain marks are common on shale bedding planes.

FRACTURING: Joints are abundant; moderately well formed; regularly spaced at close to moderate distances depending on lithology; open and vertical.

WEATHERING: Moderately resistant; shale and claystone exposures may be severely weathered, whereas sandstone and siltstone beds appear to be only slightly weathered; overlying mantle is thin in most places.

TOPOGRAPHY: Rolling valleys of medium relief; slopes are fairly steep and stable.

DRAINAGE: Good surface drainage.

POROSITY AND PERMEABILITY: Low to moderate porosity in sandstone and siltstone; joints provide abundant secondary porosity in shale, sandstone, and siltstone; total effective porosity is high; moderate to low permeability.

GROUNDWATER: Median yield is 55 gal/min; extensively developed for water supply; iron content may be high; generally, water quality is good and water is soft.

EASE OF EXCAVATION: Moderately easy to moderately difficult; depends on rock type and fracturing.

CUT-SLOPE STABILITY: Good if severe undercutting of resistant beds does not occur.

FOUNDATION STABILITY: Good; should be excavated to sound bedrock.

CONSTRUCTION MATERIALS: Good source of road material and fill; shale is good raw material for brick.

ROCK TEST DATA:
Permeability = 0.5 to 7.0 ft/day in soft sandstone
3.0 to 67 ft/day in fractured, less weathered rock
Compressive strength = 311 to 2,830 T.S.F.

REMARKS: Permeability data from SCS and compressive strengths from Conwell and Company.

MAUCH CHUNK FORMATION, GREENBRIER LIMESTONE MEMBER (included in Mmc)

DESCRIPTION: Dark-gray, fossiliferous limestone; interbedded calcareous shale; limestone is composed of small fossils and fossil fragments cemented by calcite; some quartz sand grains; includes Deer Valley Limestone tongue at base and Wymps Gap Limestone tongue at top; maximum thickness is about 60 feet; reference section is in quarry along U. S. Route 40 at the east foot of Chestnut Ridge, Fayette County.

BEDDING: Well bedded; massive.

FRACTURING: Joints have a blocky to platy pattern; well developed; moderately abundant; regularly spaced, having a moderate distance between fractures; open and nearly vertical.

WEATHERING: Moderately resistant; moderately weathered to a shallow depth; small- to medium-sized fragments result; overlying mantle is thick.

TOPOGRAPHY: Flanks of ridges in Allegheny Mountain section of Appalachian Plateaus province; slopes are steep and stable.

DRAINAGE: Good surface and minor subsurface drainage.

POROSITY AND PERMEABILITY: Joint- and bedding-plane openings provide a secondary porosity of moderate magnitude; low to moderate permeability.

GROUNDWATER: Aquifer characteristics are unknown; outcrop area is narrow, in a mountainous terrain.

EASE OF EXCAVATION: Difficult; fast drilling rate.

CUT-SLOPE STABILITY: Good.

FOUNDATION STABILITY: Good; investigation for solution cavities should be undertaken.

CONSTRUCTION MATERIALS: Good source of road material and agricultural lime.

MAUCH CHUNK FORMATION, LOYALHANNA MEMBER (included in Mmc)

DESCRIPTION: Calcareous sandstone; fine grained to coarse grained; greenish gray to bluish gray; banded by grain size; conspicuously cross banded; maximum thickness is about 50 feet; reference section is at Loyalhanna Creek gorge, Westmoreland County.

BEDDING: Very poorly developed in most places; intense cross stratification; bands or thin beds up to 2 inches thick are common.

FRACTURING: Joints form a blocky or platy pattern; moderately developed; moderately abundant; irregularly spaced, having a moderate distance between fractures; most are open and steeply dipping.

WEATHERING: Moderately resistant in predominantly carbonate part and highly resistant in siliceous portion; shallow weathering; platy rubble, containing medium-sized fragments; mantle is thin.

TOPOGRAPHY: Occurs in rough mountainous areas of moderate to high relief; natural slopes are stable at moderate to high angles.

DRAINAGE: Surface drainage is good; subsurface drainage may occur.

POROSITY AND PERMEABILITY: Primary porosity is very low; secondary porosity is good; low permeability.

GROUNDWATER: Unknown aquifer characteristics because of difficult accessibility in rough, mountainous areas and deep burial elsewhere.

EASE OF EXCAVATION: Difficult; drilling rate is moderate to slow.

CUT-SLOPE STABILITY: Good.

FOUNDATION STABILITY: Good; should include careful examination for distribution of solution openings.

CONSTRUCTION MATERIALS: Good source of road material, riprap, and concrete aggregate.

ROCK TEST DATA:
Specific gravity = 2.64 to 2.81
Absorption = 0.22 to 0.66%

REMARKS: Test data from PDT.

McKENZIE FORMATION (SEE MIFFLINTOWN FORMATION)

METABASALT (mb)

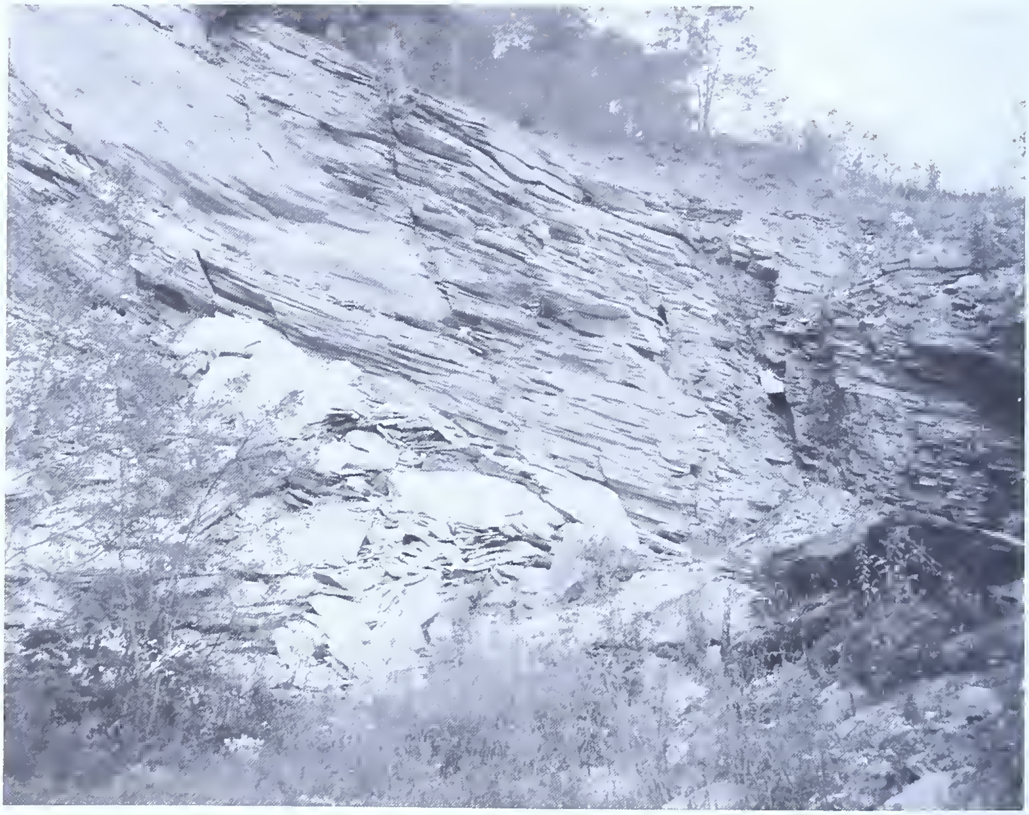
DESCRIPTION: Characteristically green, greenish gray, and dark gray; fine to medium grained; medium to coarse color banding; veins and masses of quartz; estimated thickness is in excess of 1,000 feet; reference section is in small quarry near Mt. Hope, Adams County.

BEDDING: None.

FRACTURING: Joints have a blocky pattern; moderately developed; moderately to widely spaced; open joints are characteristic, but some are filled with quartz; most are steeply dipping; flow cleavage predominates.

WEATHERING: Highly resistant; moderately weathered, mostly to a shallow depth, resulting in irregular, hackly, broken masses of medium-sized fragments; thin overlying mantle.

TOPOGRAPHY: Rough mountains of high relief; natural slopes are fairly steep and stable.



DRAINAGE: Good surface drainage.

POROSITY AND PERMEABILITY: Secondary porosity of low magnitude; low permeability.

GROUNDWATER: Median yield is 5 gal/min; yields are obtained from fractured, weathered zone at top of bedrock; water levels show strong seasonal influence; water is usually soft.

EASE OF EXCAVATION: Difficult; slow drilling rate; numerous quartz veins contribute to slow drillability.

CUT-SLOPE STABILITY: Fair to good.

FOUNDATION STABILITY: Good; should be excavated to sound material.

CONSTRUCTION MATERIALS: Good source of road material, riprap, and fill.

ROCK TEST DATA:

Blue Ridge Greenstone (metabasalt)

Apparent specific gravity = 3.11 to 3.12

Apparent porosity = 0.48 to 0.70%

Compressive strength = 26,100 to 30,100 lb/in^2

Modulus of rupture = 1,720 to 3,480 lb/in^2

Impact toughness = 3.3 to 5.3 in/in^2

Young's modulus = 3.42 to 8.70 $lb/in^2 \times 10^6$

Modulus of rigidity = 3.25 to 4.93 $lb/in^2 \times 10^6$

Longitudinal bar velocity = 8,890 to 14,400 ft/sec

REMARKS: Test data from USCE.

METADIABASE (md)

DESCRIPTION: Dark-greenish-gray to almost black diabase; generally 1/2 to 1 mm in grain size; consists of augite, feldspar (andesine to labradorite), and magnetite; extensively altered—feldspar is altered to sericite and augite has been replaced by epidote and chlorite; occurs as mostly thin dikes, but a few may be greater than 100 feet thick; reference locality is a mile south of Rittenhouse Gap, Berks County.

BEDDING: None.

FRACTURING: Joints have a blocky pattern; well developed; moderately abundant; regularly spaced, having a close to moderate distance between fractures; open and steeply dipping.

WEATHERING: Slightly to moderately resistant; weathering produces small to large blocks and rounded rock fragments mixed with a thin soil; outcrops are rare; dikes are indicated where rock fragments are present on the surface; weathered rock surface is often orange brown.

TOPOGRAPHY: Generally moderate ridges are associated with dikes.

DRAINAGE: Good surface drainage.

POROSITY AND PERMEABILITY: Joint-plane openings provide a very shallow and low secondary porosity; low permeability; effective porosity and permeability probably exist to 150 feet in depth.

GROUNDWATER: Yields of less than 5 gal/min are common.

EASE OF EXCAVATION: Moderately easy where highly fractured and weathered; difficult elsewhere and at depth.

CUT-SLOPE STABILITY: Good to fair depending on density of fractures and depth of cut.

FOUNDATION STABILITY: Excellent; should be excavated to sound bedrock.

CONSTRUCTION MATERIALS: Good source of road material, ballast, and fill.

METAGABBRO (Xmg)

DESCRIPTION: Ranges from fine- to medium-grained, altered gabbro to hornblende gneiss.

BEDDING: Banding is common; most bands are flaggy, but some are thick.

FRACTURING: Joints have an irregular pattern; moderately to poorly formed; moderate in abundance; widely to moderately spaced; irregular, steeply dipping to vertical, and open.

WEATHERING: Highly resistant; slightly weathered to a shallow depth; large, rectangular blocks are products of weathering; overlying mantle is thin.

TOPOGRAPHY: Hills of medium relief and undulating surface; natural slopes are fairly steep and stable.

DRAINAGE: Good surface drainage.

POROSITY AND PERMEABILITY: Low primary porosity; joint openings provide a low secondary porosity; low permeability.

GROUNDWATER: Median yield is 20 gal/min; highest yields are obtained from fractured, weathered zone at top of bedrock; static water levels show strong seasonal influence; water is usually soft and of good quality.

EASE OF EXCAVATION: Difficult; slow drilling rate.

CUT-SLOPE STABILITY: Good.

FOUNDATION STABILITY: Good; should be excavated to sound bedrock.

CONSTRUCTION MATERIALS: Good source of riprap, embankment facing, and fill.

METARHYOLITE (mr)

DESCRIPTION: Moderate bluish gray to grayish blue, and grayish red; some is banded; uniformly fine grained; some is porphyritic, containing phenocrysts of both quartz and feldspar; at least 1,000 feet thick; reference section is along Rocky Mountain Creek about 1 mile south of Caledonia Park, Franklin County.

BEDDING: None.

FRACTURING: Joints have a platy to irregular pattern; moderately developed; highly abundant; closely spaced and irregular; open joints are characteristic but some are filled with quartz; most are steeply dipping.

WEATHERING: Highly resistant; moderately weathered, mostly to a shallow depth, resulting in irregular, hackly, broken masses of medium-sized fragments; thin overlying mantle.

TOPOGRAPHY: Rough mountains of high relief; natural slopes are fairly steep and stable.

DRAINAGE: Good surface drainage.

POROSITY AND PERMEABILITY: Secondary porosity of low magnitude; low permeability.

GROUNDWATER: Median yield is 5 gal/min; yields are obtained from fractured, weathered zone at top of bedrock; water levels show strong seasonal influence; water is usually soft.

EASE OF EXCAVATION: Difficult; slow drilling rate; numerous quartz veins contribute to slow drilling rate.

CUT-SLOPE STABILITY: Fair to good, due to fracturing.

FOUNDATION STABILITY: Good; should be excavated to sound material.

CONSTRUCTION MATERIALS: Good source of road material, riprap, and fill.

MIFFLINTOWN FORMATION (included in Sbm, Swm, DSkm, and DSkc)

DESCRIPTION: Greenish-gray shale interbedded with medium-gray, fossiliferous limestone; shale is predominant at base; intraformational breccia occurs in lower part of formation; equivalent to "McKenzie" and "Rochester" of earlier workers; approximately 300 feet thick; type section is in roadcut on east side of U. S. Route 22, 0.3 mile north of Mifflintown, Juniata County.

BEDDING: Well bedded; fissile to thin.

FRACTURING: Joints have a platy pattern; some thin-bedded limestones have a blocky pattern; moderately well developed; moderately to highly abundant; closely spaced; steeply dipping.

WEATHERING: Only slightly resistant; moderately to highly weathered to a moderate depth; small, flat, irregularly shaped fragments result; limestone beds break up into small, flat blocks; overlying mantle is thin.

TOPOGRAPHY: Rolling to rough hills of medium to high relief; natural slopes are fairly steep and stable.

DRAINAGE: Good surface drainage.

POROSITY AND PERMEABILITY: Joint-, bedding-, and cleavage-plane openings provide a secondary porosity of low magnitude; moderate to low permeability.

GROUNDWATER: Median yield is 20 gal/min; hydrogen sulfide has been noted in some wells; water quality decreases with increased depth.

EASE OF EXCAVATION: Weathered rock is moderately difficult to moderately easy; difficult in unweathered part; fast drilling rate may be expected.

CUT-SLOPE STABILITY: Fair; shale portion is susceptible to moisture, causing short-term stability.

FOUNDATION STABILITY: Good; should be excavated to sound material; should be investigated for collapse possibilities where limestone is encountered.

CONSTRUCTION MATERIALS: Good source of road material, fill, and possible brick and expanded aggregate (shale).

MILLBACH FORMATION (€m; included in €ms)

DESCRIPTION: Pinkish-gray and medium-gray, laminated limestone; interbeds of light- to medium-gray dolomite that weathers buff to yellowish gray; approximate maximum thickness is 1,500 feet; reference section is in a small quarry about 0.75 mile south of Sheridan, Lebanon County.

BEDDING: Well bedded; thick to massive.

FRACTURING: Joints have a blocky pattern; well developed; moderately abundant; regularly spaced, having a moderate distance between fractures; open and nearly vertical.

WEATHERING: Moderately resistant; slightly weathered to a shallow depth; irregularly shaped, large-sized blocks result; thickness of overlying mantle is variable; interface between bedrock and mantle is usually characterized by pinnacles.

TOPOGRAPHY: Rolling valley of low relief; natural slopes are gentle and stable.

DRAINAGE: Good subsurface drainage; little surface drainage; sinkholes are numerous.

POROSITY AND PERMEABILITY: Solution channels provide a secondary porosity of moderate to high magnitude; high permeability.

GROUNDWATER: In the Lebanon Valley, yields of 200 to 500 gal/min are not uncommon; in the Lancaster Valley the opposite is true, and formation is a poor source for public supply and only a fair source for small public supply (37 percent of wells studied have yields greater than 25 gal/min).

EASE OF EXCAVATION: Difficult; bedrock pinnacles are a special problem; moderate drilling rate.

CUT-SLOPE STABILITY: Good.

FOUNDATION STABILITY: Good; thorough investigation should be undertaken for solution cavities.

CONSTRUCTION MATERIALS: Good source of road material, riprap, and fill.

MINISINK LIMESTONE (included in Drc)

DESCRIPTION: Fossiliferous, medium-dark-gray to dark-gray, fine-grained, clayey limestone; about 14 feet thick; reference section is about 0.8 mile north of Delaware River at Tocks Island at intersection of secondary road and the Smithfield-Middle Smithfield Township boundary, Monroe County.

BEDDING: Irregularly bedded; thin.

FRACTURING: Cleavage is well developed; joints are poorly developed and irregularly spaced, usually having a narrow distance between fractures; vertical and open.

WEATHERING: Moderately resistant; moderately weathered to a shallow depth; small- to medium-sized, smooth fragments result; overlying mantle is thin to moderately thick.

TOPOGRAPHY: Forms flanks of ridges of medium relief; natural slopes are steep and stable.

DRAINAGE: Good surface drainage.

POROSITY AND PERMEABILITY: Joint-, bedding-, and cleavage-plane openings provide a secondary porosity of moderate magnitude; moderate permeability.

GROUNDWATER: Yields of more than 100 gal/min may be possible; water is very hard; very thin unit having limited outcrop width; specific aquifer characteristics are unknown.

EASE OF EXCAVATION: Difficult; fast drilling rate.

CUT-SLOPE STABILITY: Good.

FOUNDATION STABILITY: Good; should be excavated to sound bedrock.

CONSTRUCTION MATERIALS: Good source of random fill.

MONONGAHELA GROUP (IPm)

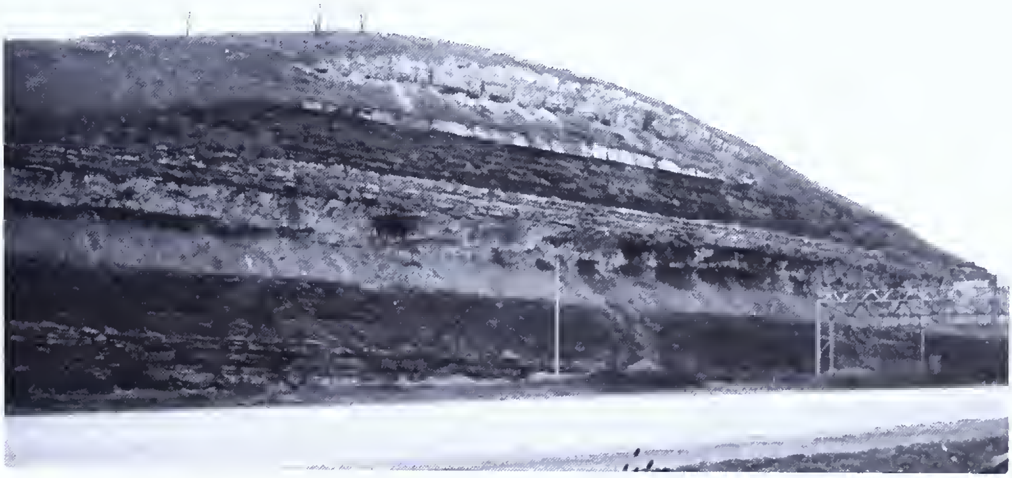
DESCRIPTION: Cyclic sequences of shale, limestone, sandstone, siltstone, claystone, coal, and underclay; may be over 50 percent limestone; upper and lower portions contain sandstone, shale, and claystone; commercial coals are present in lower portion; sandstone is light gray, fine to medium grained, and argillaceous; limestone, shale, and claystone are medium to dark gray; limestone is very argillaceous and weathers buff to olive gray; base is at bottom of Pittsburgh coal; approximately 270 to 350 feet thick; type area is along the Monongahela River in southwestern Pennsylvania.

BEDDING: Well developed; thin beds in sandstone and siltstone; thicker beds in limestone; shale is fissile or very thin; claystone shows very poor bedding.

FRACTURING: Joints are poorly to moderately well developed in sandstone and siltstone; poorly developed in claystone and shale; moderately to well developed in limestone; widely spaced in irregular intervals; blocky or platy pattern; spacing is closer in finer grained rocks; open and vertical.

WEATHERING: Limestone and sandstone are moderately resistant and weather to a shallow depth; shale, claystone, siltstone, and coal weather deeper and more rapidly; thin to moderate mantle cover.

TOPOGRAPHY: Rough plateau topography of medium relief; streams form assortment of irregular, rounded ridges and hills; sandstone and



limestone have noticeable effect on relief and direction of topographic features; areas of steeper structural dips display deeper, narrower stream valleys separated by broad-topped, steep-sided divides; moderate to fairly steep natural slopes are stable.

DRAINAGE: Surface drainage varies from fair to good; subsurface drainage may occur in limestone.

POROSITY AND PERMEABILITY: Very little primary porosity; porosity of sandstone is generally fair; secondary porosity from well-developed joint systems; low porosity and permeability.

GROUNDWATER: Sandstone and limestone are primary water-bearing rocks; median yield is 15 gal/min; some wells yield more than 100 gal/min; iron and hardness are frequent problems; careful well construction should be employed to prevent contamination of groundwater in oil and gas fields and mined-out coal areas.

EASE OF EXCAVATION: Fine-grained rocks have moderately easy excavation; difficult excavation in sandstone; drilling rate is moderate to fast.

CUT-SLOPE STABILITY: Good, except where excessive undercutting of resistant limestone and sandstone beds occurs.

FOUNDATION STABILITY: Good; foundations should not be placed on or in underclay and claystone because they tend to deform under load when wet; careful attention should be directed to precise location of mined-out coal areas due to possible subsidence under heavy loads.

CONSTRUCTION MATERIALS: Good source of fill and road material; sandstone is source of embankment facing and building stone if not too platy.

MYERSTOWN FORMATION (Ohm; included in Oha)

DESCRIPTION: Medium- to dark-gray, medium-crystalline limestone; dark-gray to black carbonaceous limestone at base; coarse calcarenite beds are common; average thickness is about 220 feet; reference section is the abandoned H. E. Millard quarry at Millardsville, Lebanon County.

BEDDING: Well bedded; thin to flaggy.

FRACTURING: Joints have a platy pattern; well developed; highly fractured; moderate distance between fractures; steeply dipping and open.

WEATHERING: Moderately resistant; moderately to highly weathered to a moderate depth; pencil-like, jagged fragments to medium size, elongate plates, and blocks result; overlying mantle is thin.

TOPOGRAPHY: Rolling valleys of low relief; natural slopes are gentle and stable.

DRAINAGE: Good surface and minor subsurface drainage.

POROSITY AND PERMEABILITY: Joint and solution openings provide a secondary porosity of low magnitude; low to moderate permeability.

GROUNDWATER: Median yield is 25 gpm; wells have encountered solution openings for very large yields; water can be relatively hard.

EASE OF EXCAVATION: Moderately easy; difficult at depth where rock is unweathered; moderate drilling rate.

CUT-SLOPE STABILITY: Fair, due to disintegration when exposed to moisture for a relatively short time.

FOUNDATION STABILITY: Good; should be investigated thoroughly for solution openings.

CONSTRUCTION MATERIALS: Good source of road material and fill.

NEALMONT FORMATION (included in Ocn and Ocl)

DESCRIPTION: Medium-gray, coarsely crystalline, fossiliferous limestone at top (Rodman Member); thin-bedded, finely crystalline, shaly limestone at base (Centre Hall Member); approximately 75 feet thick in central Pennsylvania; reference section is at Reedsville, Mifflin County.

BEDDING: Well bedded; usually fissile to flaggy; rarely thick bedded.

FRACTURING: Joints have a blocky pattern; a few have a platy pattern; moderately well developed; moderately to highly abundant; fairly regular, having a moderate distance between fractures; most fractures are open but some are filled with calcite; steeply dipping to vertical.

WEATHERING: Moderately resistant; slightly weathered to a shallow depth; medium-sized blocks commonly result; overlying mantle is moderately thick; the bedrock-mantle interface is usually characterized by pinnacles.

TOPOGRAPHY: Rolling valleys of low relief; natural slopes are gentle and stable.

DRAINAGE: Good subsurface drainage; poor surface drainage; sinkholes are common.

POROSITY AND PERMEABILITY: Joint and solution openings provide a secondary porosity of moderate to high magnitude; moderately permeable.

GROUNDWATER: Median yield is 50 gal/min; water is sometimes hard.

EASE OF EXCAVATION: Difficult; bedrock pinnacles are a special problem; fast drilling rate.

CUT-SLOPE STABILITY: Good; in steeply dipping beds inclined toward the roadway, stability is only fair.

FOUNDATION STABILITY: Good; should be excavated to sound material and should involve a thorough investigation for possible collapse areas.

CONSTRUCTION MATERIALS: Good source of road material and fill.

ROCK TEST DATA:
Specific gravity = 2.70
Absorption = 0.32%

REMARKS: Test data from PDT.

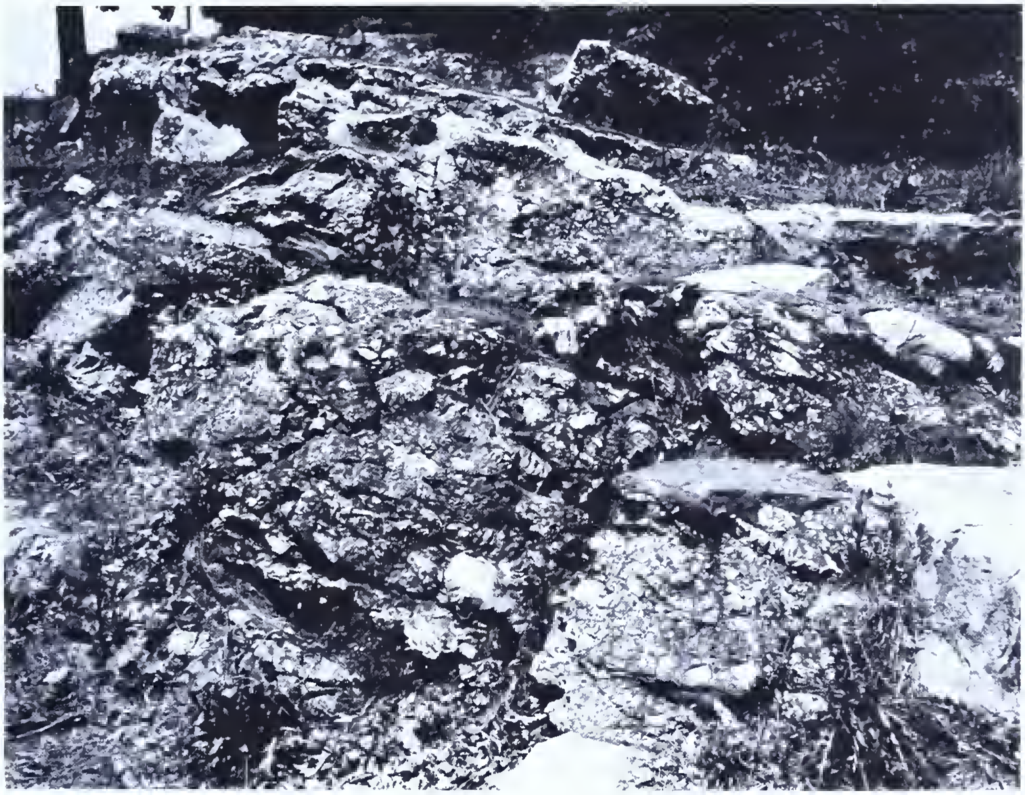
NEEDMORE FORMATION (SEE ONONDAGA FORMATION)

NEW OXFORD FORMATION, CONGLOMERATE (Trnc)

DESCRIPTION: Coarse conglomerate, consisting chiefly of quartz and quartzite pebbles, cobbles, and boulders in a poorly sorted, red-brown sand matrix; conglomerates are most numerous near the base of the formation; the lower half of the formation is approximately 3,000 feet thick; reference section is in small quarry along Pa. Route 194, about 1 mile south of Abbottstown, Adams County.

BEDDING: Well bedded; thick.

FRACTURING: Semiblocky pattern; moderately developed; widely spaced; vertical and open.



WEATHERING: Moderately resistant; sand matrix weathers slowly, and plucking of pebbles is evident; overlying mantle is thin.

TOPOGRAPHY: Discontinuous ridges that rise slightly above the general surface of the rolling plain.

DRAINAGE: Good surface drainage.

POROSITY AND PERMEABILITY: Low to moderate primary porosity, especially in weathered zone; joint- and bedding-plane openings provide a secondary porosity; low permeability.

GROUNDWATER: Average yield is about 14 gal/min.

EASE OF EXCAVATION: Difficult; relatively slow drilling rate may be expected.

CUT-SLOPE STABILITY: Good to fair; slow disintegration of sand matrix when exposed to moisture for a relatively long time.

FOUNDATION STABILITY: Good; should be excavated to sound material.

CONSTRUCTION MATERIALS: Good source of fill.

NEW OXFORD FORMATION, SHALE AND SANDSTONE (Trn)

DESCRIPTION: Light-colored sandstone, arkosic sandstone, and conglomeratic sandstone; includes red to purplish-red sandstone, shale, and mudstone; total thickness is approximately 4,000 feet and represents the upper half of the formation; reference section is in quarries southeast of borough of New Oxford, Adams County.

BEDDING: Well bedded; thin to flaggy.

FRACTURING: Joints have a seamy to platy pattern; moderately developed; highly fractured; very close spacing; vertical and open.

WEATHERING: Only slightly resistant; exposures are quickly weathered to a moderate depth; very small, pencil-like, platy fragments result from rapid disintegration; overlying mantle is thin.

TOPOGRAPHY: Gently rolling plain; broad shallow valleys and low, flat-topped ridges; stable.

DRAINAGE: Good surface drainage.

POROSITY AND PERMEABILITY: Primary porosity occurs in weathered portion; joint- and bedding-plane openings provide a secondary porosity in unweathered rock; high to moderate total effective porosity; moderate permeability.

GROUNDWATER: Median yield is 66 gal/min; hardness and total dissolved solids are frequently high.

EASE OF EXCAVATION: Moderately easy; relatively fast drilling rate may be expected.

CUT-SLOPE STABILITY: Poor to fair, due to rapid disintegration when exposed to moisture for a relatively short time.

FOUNDATION STABILITY: Good; should be excavated to sound material; underdrainage may possibly be required.

CONSTRUCTION MATERIALS: Good source of brick, floor tile, and sintered aggregate material.

ROCK TEST DATA:
Absorption = 3.0%
Specific gravity (bulk, saturated surface, dry) = 2.57
Water of plasticity = 16 to 19%
Drying shrinkage = 1.5 to 3.5%

REMARKS: Test data from USBM.

NEW SCOTLAND FORMATION (included in Drc)

DESCRIPTION: Medium-dark-gray to dark-gray, fossiliferous, silty, limy shale interbedded with medium-gray, clayey, fine-grained limestone; nodules and nodular beds of dark-gray chert; about 75 feet thick; reference section is in small quarry, Ross Township, Monroe County.

BEDDING: Moderately well bedded; thin to thick.

FRACTURING: Joints and cleavage are well developed; irregular spacing, in most cases having a narrow distance between fractures, but widely spaced in coarser rocks; joints are nearly vertical and open.

WEATHERING: Moderately resistant; moderately weathered to a moderate depth; small, tabular to pencil-shaped fragments result; chert breaks into larger, hackly blocks; chert weathers to reddish gray to pale orange; overlying mantle is moderately thick.

TOPOGRAPHY: Elongate ridges of medium relief; natural slopes are steep and stable.

DRAINAGE: Good surface drainage.

POROSITY AND PERMEABILITY: Joint-, bedding-, and cleavage-plane openings provide a secondary porosity of moderate magnitude; moderate permeability.

GROUNDWATER: Yields of greater than 100 gal/min may be possible; water is moderately hard.

EASE OF EXCAVATION: Moderately difficult; chert will slow the normally fast drilling rate.

CUT-SLOPE STABILITY: Fair; limy shale disintegrates and slumps.

FOUNDATION STABILITY: Good; should be excavated to sound bedrock.

CONSTRUCTION MATERIALS: Good source of random fill.

NITTANY FORMATION (On; included in Ons)

DESCRIPTION: Light- to dark-gray, finely to coarsely crystalline dolomite; in part, alternating beds of light- and dark-gray dolomite; sandy; cherty; approximate thickness is 1,250 feet; reference section is represented by exposures in Nittany Valley, Centre County.

BEDDING: Moderately well bedded to well bedded; thick to massive.

FRACTURING: Joints have a seamy pattern; wide range from well developed to poorly developed; moderately abundant; moderate distance between fractures; open and steeply dipping to vertical.

WEATHERING: Moderately resistant; slightly weathered to a shallow depth; small- to medium-sized, flat, rectangular fragments result; overlying mantle varies in thickness, and is greater than 80 feet in some places; bedrock pinnacles.

TOPOGRAPHY: Rolling valleys of low relief; gentle and stable natural slopes.

DRAINAGE: Good subsurface drainage; sinkholes and caves are characteristic.

POROSITY AND PERMEABILITY: Joint and solution-channel openings provide a secondary porosity of low to moderate magnitude; moderate to high permeability.

GROUNDWATER: Median yield is 100 gal/min; high yields due to fractures and solution cavities; water is relatively hard.

EASE OF EXCAVATION: Difficult; bedrock pinnacles are a special problem; fast drilling rate.

CUT-SLOPE STABILITY: Good in most areas; fair locally.

FOUNDATION STABILITY: Good; should be excavated to sound bedrock and thoroughly investigated for solution openings.

CONSTRUCTION MATERIALS: Good source of road material and fill.

ROCK TEST DATA:
Compressive strength = 10,900 to greater than 27,000 lb/in^2

REMARKS: Test data from VU; core samples 4 to 6 inches in length.

NORTHEAST SHALE (Dne)

DESCRIPTION: Medium-gray and greenish-gray shale, siltstone, and fine-grained sandstone; included in ''Chemung'' by earlier workers; 415 feet thick; reference section is in North East Township, Erie County.

BEDDING: Mostly well developed; generally less than 2 inches thick; flaggy and platy.

FRACTURING: Well developed; closely spaced in shale and siltstone; most form a blocky or platy pattern; open and steeply dipping or vertical.

WEATHERING: Shale disintegrates rapidly when exposed to moisture, resulting in small, platy, triangular fragments; sandstone and siltstone are moderately resistant and break up into small to medium blocks; mantle is thick in glaciated areas of northwestern Pennsylvania, and variable in thickness elsewhere.

TOPOGRAPHY: Plateau of low to medium relief; bedrock topography is masked by glacial material.

DRAINAGE: Surface drainage is moderate to good; in glaciated regions, drainage is poor.

POROSITY AND PERMEABILITY: Interstitial porosity is low in coarser rocks; joint development creates a moderate total effective porosity; low permeability.

GROUNDWATER: The median yield is 4 gal/min; wells greater than 100 feet in depth usually encounter salt water; generally a poor aquifer; yields range from 0.1 to 25 gal/min in Erie County; salt water and pockets of natural gas are common.

EASE OF EXCAVATION: Moderately difficult; relative drillability is moderate.

CUT-SLOPE STABILITY: Good to fair in sandstone; siltstone and shale disintegrate rapidly; undercutting of resistant beds can cause poor-quality slopes and result in rockfalls; drainage maintenance is required.

FOUNDATION STABILITY: Good; shale and siltstone should be kept water free; must be excavated to sound bedrock.

CONSTRUCTION MATERIALS: Fair source of brick raw material and fill.

OLD PORT FORMATION (includes Dor and Dosn; included in Doo)

DESCRIPTION: The formation contains diverse rock types including sandstone, chert, shale, and limestone. Includes in descending order: *Ridgeley Member*—fine- to very coarse grained, light-gray, porous sandstone (''Oriskany'' of earlier geologists); *Shriver Member*—dark-gray to black chert that weathers to light gray to white or yellow brown; *Mandata* *and Corriganville Members*—gray-brown, silty to very sandy shale, siltstone, and chert; *New Creek Member*—medium-gray to dark-gray calcareous shale and interbedded light- to medium-gray limestone. In Fulton County, limestone and chert of the Licking Creek Member replaces the Shriver and Mandata Members. The Old Port Formation of central and east-central Pennsylvania has been mapped often as a single rock unit because the members are thin, locally absent, or poorly exposed; the rock type most characteristic of the Old Port is a whitish-weathering, dark-gray to black chert, overlain by porous sandstone and underlain by shale and limestone; approximately 100 feet thick; reference section is on Maple Street in Beaver Springs, Snyder County.

BEDDING: Well bedded; thin to massive.

FRACTURING: Joints are well developed; highly abundant; close to moderately spaced; both open and filled with calcite.

WEATHERING: Variable, but mostly moderately resistant; mostly a blocky pattern, producing rough, sharp-edged fragments in the soil;

some tabular fragments; fossils and quartz crystals are present in the weathered fragments; overlying mantle is thin.

TOPOGRAPHY: Ridge crest; moderately high and of medium relief; natural slopes are steep and stable.

DRAINAGE: Good surface drainage.

POROSITY AND PERMEABILITY: In part of the formation, the porosity may be greater than 20 percent; moderate to high permeability.

GROUNDWATER: Median reported yield is 10 gal/min; yield ranges from 1 to 100 gal/min; median hardness is 2 grains per gallon.

EASE OF EXCAVATION: Difficult; slow drilling rate.

CUT-SLOPE STABILITY: Good in most places; highly jointed; where jointing is parallel to cut and dip is steep into cut, stability is fair to poor.

FOUNDATION STABILITY: Good; should be excavated to sound bedrock.

CONSTRUCTION MATERIALS: Good source of road material, sand, glass sand, and fill.

OLD PORT FORMATION, NEW CREEK MEMBER (included in Dosn and Doo)

DESCRIPTION: Dark-gray to medium-gray, calcareous shale; fossiliferous; interbedded light- to medium-dark-gray limestone grading to all limestone at base; approximately 70 feet thick; reference section is at base of type section of Old Port Formation.

BEDDING: Well developed; thin to medium.

FRACTURING: Joints are moderately well developed; irregular spacing; open and steeply dipping.

WEATHERING: Slight to moderately weathered; shale chips and medium-sized limestone blocks result.

TOPOGRAPHY: Moderately high ridges; medium to high relief; natural slopes are steep and stable.

DRAINAGE: Good surface drainage.

POROSITY AND PERMEABILITY: Secondary porosity (joint, bedding, and fault openings) is low to moderate; low permeability.

GROUNDWATER: Median yield is less than 20 gal/min; water quality is good.

EASE OF EXCAVATION: Moderately difficult; drilling rate is fast.

CUT-SLOPE STABILITY: Good to fair; shale may disintegrate rather rapidly.

FOUNDATION STABILITY: Good; should be excavated to fresh bedrock.

CONSTRUCTION MATERIALS: Good source of fill.

OLD PORT FORMATION, RIDGELEY MEMBER (Dor; included in Doo)

DESCRIPTION: Sandstone, fine- to very coarse grained, pebbly; white, and light gray to buff; fossiliferous; "Oriskany" of earlier workers; maximum thickness is about 50 feet; reference section is along U.S. Route 22–322 at Midway, Perry County.

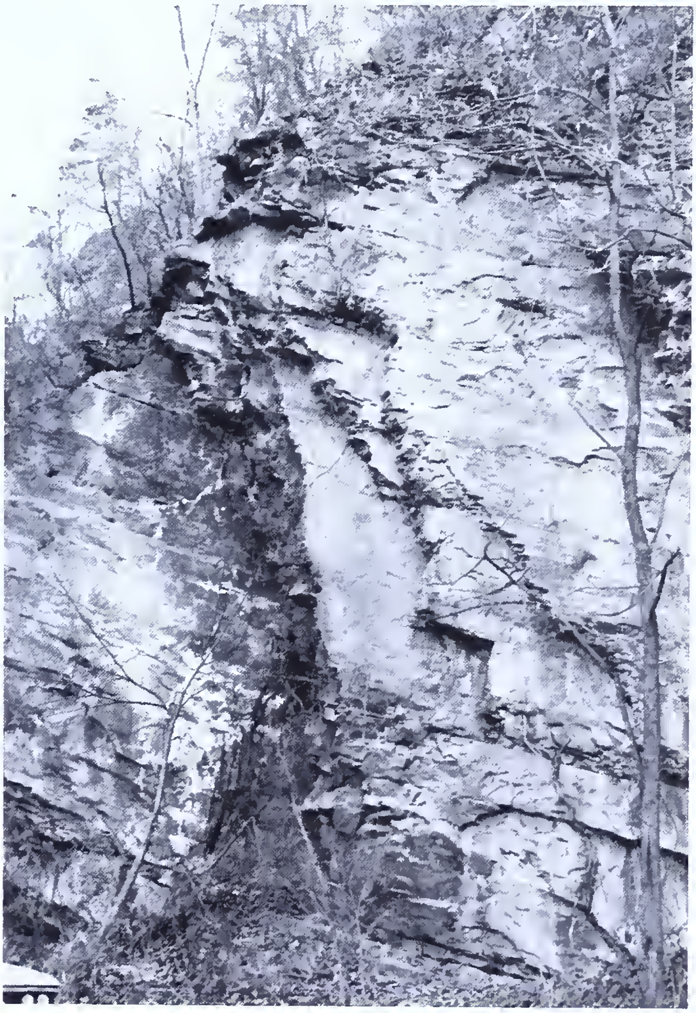
BEDDING: Moderately to well developed; medium to thick bedded.

FRACTURING: Joints are moderately well developed; moderate distribution; irregular to regular spacing at moderate distances; open and steeply dipping to vertical; in intensely folded and faulted areas, joints are highly abundant.

WEATHERING: Highly variable, depending on presence of siliceous cement; in weakly cemented sections, disintegrates to grains in a relatively short period of exposure; well-cemented sandstone is very resistant; rubble consists of individual grains to large blocks; overlying mantle is thin.

TOPOGRAPHY: Hogbacks and moderately high ridges; medium to high relief in rough terrain; natural slopes are fairly steep and stable.

DRAINAGE: Good surface drainage.



POROSITY AND PERMEABILITY: Porosity may be greater than 20 percent.

GROUNDWATER: Yields of up to 100 gal/min have been reported; quality of water is usually good.

EASE OF EXCAVATION: Variable; tightly cemented rocks have difficult excavation; friable rocks are easily excavated; drilling rate is slow.

CUT-SLOPE STABILITY: Resistant beds have good cut-slope stability; weaker rock units that have jointing parallel to cut and steep dip into cut have poor stability.

FOUNDATION STABILITY: Well-cemented, resistant rock provides a good foundation; should be excavated to sound bedrock.

CONSTRUCTION MATERIALS: Good source of refractory sand, glass sand, fill, and road material.

ROCK TEST DATA:
Absorption = 0.30%
Specific gravity (bulk, saturated surface, dry) = 2.60

REMARKS: Test data from USCE.

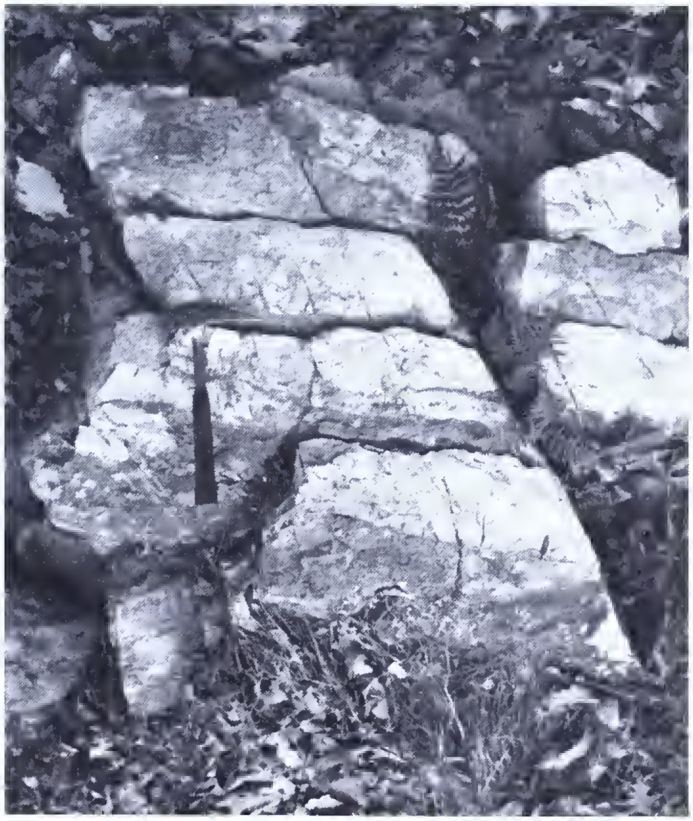
OLD PORT FORMATION, SHRIVER MEMBER (included in Dosn and Doo)

DESCRIPTION: Dark-gray to black chert; becomes light gray to white or yellow brown on weathering; very fine grained to cryptocrystalline; radial structure; mixed with calcite and quartz silt; fossiliferous; maximum thickness is about 50 feet; reference section is on Maple Street in Beaver Springs, Snyder County.

BEDDING: Well bedded; nodular; thin to massive.

FRACTURING: Joints are highly developed; most are regularly spaced, having a moderate to wide spacing; moderately abundant; many are open but some are filled with calcite or quartz.

WEATHERING: Highly resistant; block shaped; hackly, rough fragments are present in the soil; fossils weather from fragments; mantle is thin.



TOPOGRAPHY: Low ridges of medium relief; natural slopes are steep and stable.

DRAINAGE: Good surface drainage.

POROSITY AND PERMEABILITY: Joint- and bedding-plane openings provide a secondary porosity of low magnitude; low permeability.

GROUNDWATER: Yields of less than 5 gal/min are common; topographic position is unfavorable; water is soft and usually of good quality.

EASE OF EXCAVATION: Difficult; near-surface fractured rock is moderately difficult; moderate to fast drilling rate.

CUT-SLOPE STABILITY: Fair; breaks down rapidly along joint and bedding planes; rockfalls are common.

FOUNDATION STABILITY: Excellent; should be excavated to sound bedrock.

CONSTRUCTION MATERIALS: Good source of fill material.

OLEAN CONGLOMERATE (included in IPp)

DESCRIPTION: A coarse conglomerate of well-rounded pebbles of white quartz; sandstone matrix; pebbles are usually stained yellowish brown; maximum thickness is 70 feet; reference section is at Jakes Rocks, Allegheny National Forest, Warren County.

BEDDING: Well bedded; massive.

FRACTURING: Joints have a blocky pattern; well developed; regularly spaced, having a wide distance between fractures; steeply dipping; open.

WEATHERING: Highly resistant; weathered along fracture planes; small to very large blocks result; overlying mantle is thin; ''rock cities'' are common.

TOPOGRAPHY: Isolated, flat tops of high plateau in northwestern and north-central Pennsylvania.

DRAINAGE: Good surface drainage.

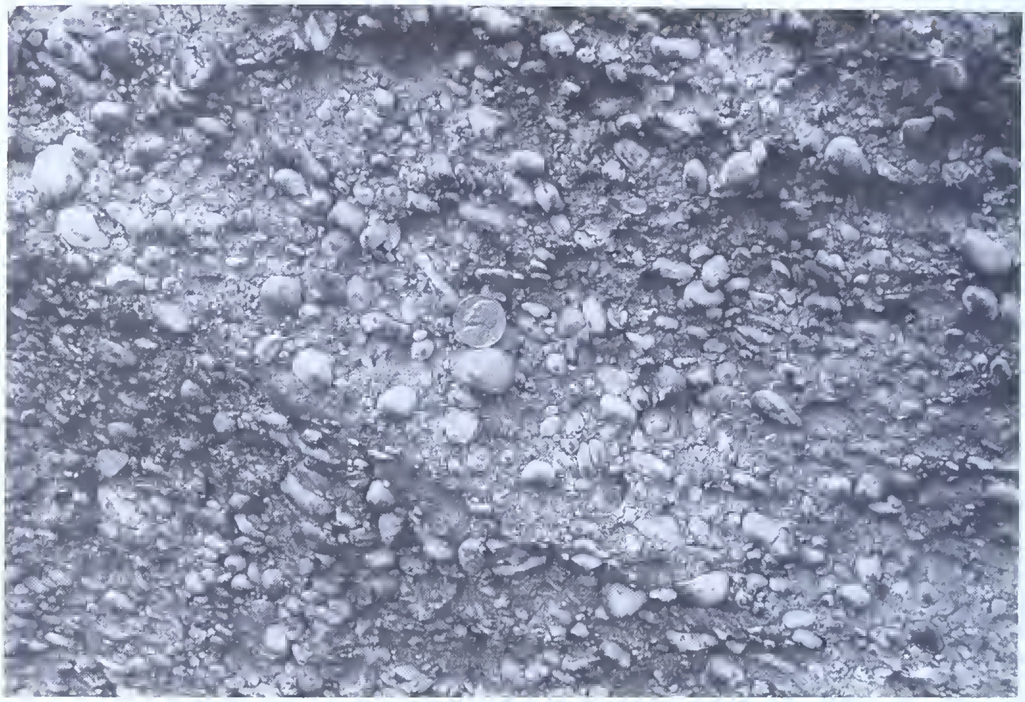
POROSITY AND PERMEABILITY: Low to moderate primary porosity; secondary porosity from fracture openings is also low to moderate; permeability is low.

GROUNDWATER: Very thin unit; usually present above the water table; if present below the water table, very low yields may be expected.

EASE OF EXCAVATION: Difficult; relative drillability is slow.

CUT-SLOPE STABILITY: Good; stable in vertical cliffs.

FOUNDATION STABILITY: Good.



CONSTRUCTION MATERIALS: Good source of fill; very limited supply.

ONONDAGA FORMATION (Don; included in Doo and DSop)

DESCRIPTION: Olive-green-weathering, medium-gray limestone and calcareous shale; claystone in lower part; Selinsgrove Limestone Member at top is dark gray and fossiliferous; called "Needmore Formation" west of 78° longitude; approximate maximum thickness is 150 feet; reference section is along Tuscarora Creek, east of Old Port School, Juniata County.

BEDDING: Well bedded; flaggy to thick.

FRACTURING: Joints have a blocky to seamy pattern; fairly well developed; moderately abundant; moderately to closely spaced; open and vertical.

WEATHERING: Moderately weathered to a deep depth; shales tend to weather deeper; results in small- to medium-sized blocks and elongate fragments at base of exposure; overlying mantle is thin in most places.

TOPOGRAPHY: Rolling hills of medium relief; natural slopes are fairly steep and stable.

DRAINAGE: Good surface drainage.

POROSITY AND PERMEABILITY: Joint- and bedding-plane openings provide a secondary porosity of moderate magnitude; moderate to low permeability.

GROUNDWATER: Median yield is 30 gal/min; water from shale frequently contains iron and hydrogen sulfide; solution channels in limestone may yield moderate to large amounts.

EASE OF EXCAVATION: Difficult; fast drilling rate.

CUT-SLOPE STABILITY: Good; shale beds may be only fair.

FOUNDATION STABILITY: Good; should be excavated to sound material; limestone should be thoroughly investigated for solution cavities.

CONSTRUCTION MATERIALS: Good source of road material and fill.

ROCK TEST DATA:
Absorption = 0.20% to 0.30%
Specific gravity (bulk, saturated surface, dry) = 2.70

REMARKS: Test data from USCE; sample size was 3/4 to 1-1/2 inches.

ONTELAUNEE FORMATION (Oo; included in Ob)

DESCRIPTION: Light- to dark-gray, very fine to medium-crystalline dolomite; interbedded and nodular dark-gray chert at base; average thickness is about 750 feet; reference section is in abandoned quarry 0.15 mile west of Coheva, Lebanon County.

BEDDING: Well bedded; thick.

FRACTURING: Joints have a blocky pattern; moderately to well developed; moderately abundant; regularly spaced, having a moderate distance between fractures; both a steeply dipping set and a gently dipping set occur; most are open but some are filled with calcite.

WEATHERING: Moderately resistant; slightly weathered to a shallow depth; small to large, blocky fragments result; overlying mantle is variable in thickness, greater than 5 feet in most places; bedrock pinnacles are characteristic.

TOPOGRAPHY: Flat to rolling valleys of low relief; gentle and stable natural slopes.

DRAINAGE: Good subsurface drainage; minor surface drainage.

POROSITY AND PERMEABILITY: Joint and solution-channel openings provide a secondary porosity of moderate to high magnitude; generally highly permeable.

GROUNDWATER: Wells in excess of 200 to 500 gal/min are common; industrial and public supplies of groundwater are available; water is relatively hard.

EASE OF EXCAVATION: Difficult; bedrock pinnacles are a special problem; fast drilling rate; chert beds and lenses slow the drilling rate.

CUT-SLOPE STABILITY: Good; intersection of joint and bedding surfaces may create a problem if the depth of cut is extreme.

FOUNDATION STABILITY: Good; should be investigated thoroughly for solution cavities.

CONSTRUCTION MATERIALS: Good source of road material, riprap, building stone, embankment facing, and fill.

ROCK TEST DATA:
Specific gravity = 2.79
Absorption = 0.64%

REMARKS: Test data from PDT.

ORISKANY SANDSTONE (SEE OLD PORT FORMATION, RIDGELEY MEMBER)

OSWAYO FORMATION (included in MDso)

DESCRIPTION: Interbedded olive-brown and greenish-gray sandy shale, olive-brown, fine-grained sandstone, and gray to olive shale, mudstone, and siltstone; marine fossils; maximum thickness is about 250 feet; type section is in vicinity of Oswayo Creek, Cattaraugus County, New York.

BEDDING: Well developed; thin and flaggy; locally thick bedded.

FRACTURING: Variably developed joints; blocky and platy patterns; highly abundant; irregular; moderately to closely spaced; open and steeply dipping to vertical.

WEATHERING: Moderately weathered to a moderate depth; if exposed to heavy drainage, silty shale and shale sections severely disintegrate; rubble is small, flat, and pencil shaped; overlying mantle is thin to moderate.

TOPOGRAPHY: Rolling terrain of medium relief in plateau region; stable natural slopes at moderate angles.

DRAINAGE: Good surface drainage.

POROSITY AND PERMEABILITY: Low effective porosity, mainly from joints; low permeability.

GROUNDWATER: Average of median yields reported is 28 gal/min; sandstone is not as productive as other sandstones on the plateau; salt water and hydrogen sulfide are often encountered.

EASE OF EXCAVATION: Difficult; moderate drilling rate.

CUT-SLOPE STABILITY: Fair; undercutting is prevalent in shale and siltstone underneath resistant sandstone beds; moisture contributes to rapid deterioration of shale, mudstone, and siltstone; support-drainage maintenance may be required.

FOUNDATION STABILITY: Good; should be excavated to sound bedrock.

CONSTRUCTION MATERIALS: Good source of road material and fill.

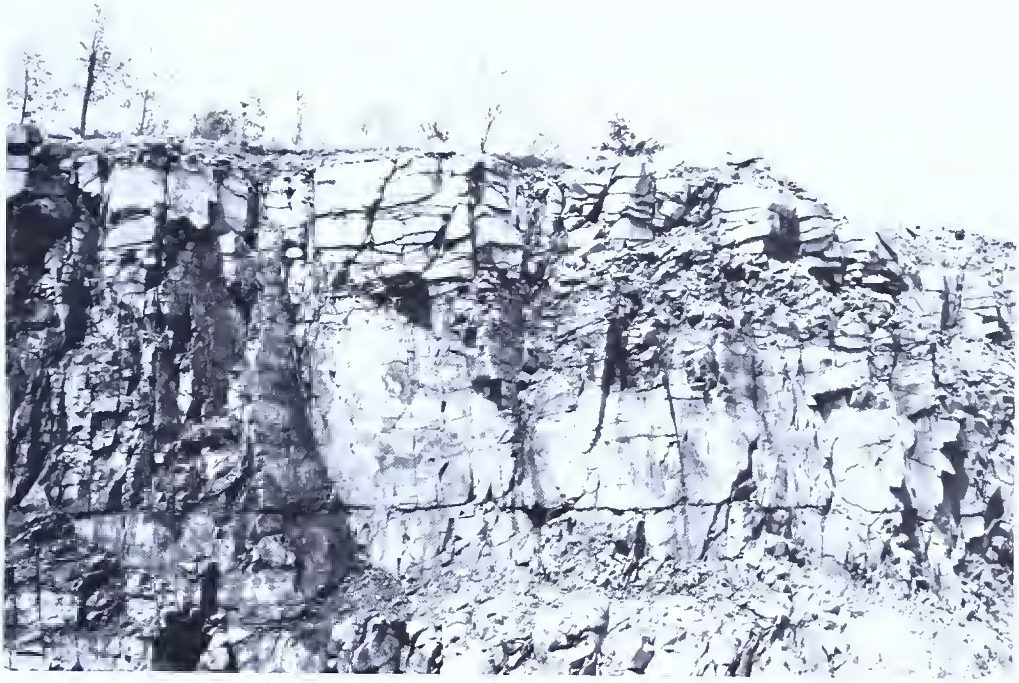
PALMERTON SANDSTONE (included in Dbe)

DESCRIPTION: White, fine- to coarse-grained, variably cemented sandstone; thickness is 100 feet; reference section is in quarry 0.5 mile northeast of Hazard School, borough of Palmerton, Carbon County.

BEDDING: Massive; lacks definite bedding planes.

FRACTURING: Joints are highly developed in a blocky pattern and are a dominant characteristic of the unit; irregular spacing, generally 2 to 10 feet; open from 2 to 40 mm.

WEATHERING: Variable, due to unpredictable variation in silica cementation; generally resistant; moderately weathered to a shallow depth; mantle is thin to thick and is made up of blocky talus.



TOPOGRAPHY: Forms ridge crests of moderate relief and a prominent wall where steeply dipping; natural slopes are fairly steep to nearly vertical; stable to unstable in areas of rockfall where there is evidence of past movement.

DRAINAGE: Good surface drainage.

POROSITY AND PERMEABILITY: Joint openings provide low to moderate secondary porosity; low permeability.

GROUNDWATER: Aquifer potential is unknown, but probably low.

EASE OF EXCAVATION: Moderately easy to difficult depending on variations in silica cementation; drilling rate is moderate to slow.

CUT-SLOPE STABILITY: Fair; steep cuts are subject to rockfall.

FOUNDATION STABILITY: Excellent after removal of weathered blocks and unconsolidated overburden.

CONSTRUCTION MATERIALS: Good source of fine aggregate, crushed stone, riprap, and rock protection.

PANAMA CONGLOMERATE (SEE VENANGO FORMATION)

PATAPSCO FORMATION (Kp)

DESCRIPTION: Variegated clay having shades of red, gray, and chocolate, interbedded with sandy clay, light-colored sand, and gravelly sand; approximately 80 feet thick; type section is in Patapsco River basin in Maryland.

BEDDING: Well bedded; cross stratified in part.

FRACTURING: None apparent.

WEATHERING: Deeply weathered.

TOPOGRAPHY: High terrace remnants parallel to the Delaware River.

DRAINAGE: Good surface drainage.

POROSITY AND PERMEABILITY: Moderate to high porosity and permeability.

GROUNDWATER: Reported well yields range from 12 to 500 gal/min; average yield is 89 gal/min.

EASE OF EXCAVATION: Easy; fast drilling rate.

CUT-SLOPE STABILITY: Poor.

FOUNDATION STABILITY: Poor; some replacement, compaction, and drainage facilities may be necessary.

CONSTRUCTION MATERIALS: Good source of sand.

PEACH BOTTOM SLATE (included in Xpb)

DESCRIPTION: Dark-gray slate and slaty schist, having rare sandy interbeds near the base; about 1,000 feet thick; reference section is at Delta, York County.

BEDDING: Cleavage surfaces have high luster and show no traces of bedding; quartzitic interbeds are very thin.

FRACTURING: Folded slaty cleavage is common; joints are both regular and irregular at different locations, and are vertical and open; faults are present.

WEATHERING: Moderately resistant; moderately weathered to a moderate depth; cleavage surfaces weather to a dull olive gray and, after prolonged weathering, to reddish brown; irregularly shaped, platy fragments result; mantle is thin.

TOPOGRAPHY: Dissected upland; upland divides have gentle slopes; ravines have steep walls; stable slopes; "slate ridge" through part of area.

DRAINAGE: Good surface drainage.

POROSITY AND PERMEABILITY: Fractures provide a low secondary porosity and low permeability.

GROUNDWATER: Median yield is 20 gal/min; static water levels show strong seasonal influence; water is usually soft and of good quality.

EASE OF EXCAVATION: Difficult; fast drilling rate; quartzitic beds may slow the drilling rate.

CUT-SLOPE STABILITY: Good.

FOUNDATION STABILITY: Good; should be excavated to sound, unweathered rock.

CONSTRUCTION MATERIALS: Good source of slate, roofing granules, and fill.

ROCK TEST DATA:
Crushing strength (average) = 11,260 lb/in^2

REMARKS: Test data from Behre (1933).

PEGMATITE (Xpg)

DESCRIPTION: White to brown color; variable grain size from 1 mm to several inches; common minerals are quartz, orthoclase, microcline, albite, biotite, and muscovite; thickness varies from a few inches to tens of feet; reference site is 1.5 miles northwest of Coatesville, Chester County.

BEDDING: None; some pegmatites are "zoned," having one or more minerals dominant in each zone; zones are parallel to the walls of the pegmatite.

FRACTURING: Usually highly fractured; fractures are closely spaced and open.

WEATHERING: Highly weathered to a deep depth after exposure for only a relatively short time; dark-colored, iron-rich minerals weather to a brown color.

TOPOGRAPHY: Rolling uplands of low relief; natural slopes are gentle and stable.

DRAINAGE: Good surface drainage.

POROSITY AND PERMEABILITY: Fractures provide a very low porosity and permeability.

GROUNDWATER: Extremely low yields may be expected; outcrop is too narrow in most places to determine specific yield of pegmatite.

EASE OF EXCAVATION: Weathered portion is moderately easy; fresh rock is difficult; drilling rate is fast.

CUT-SLOPE STABILITY: Poor; rapid weathering reduces pegmatite to loose sand-sized mineral fragments.

FOUNDATION STABILITY: Good; should be excavated to sound bedrock.

CONSTRUCTION MATERIALS: Good source of fill material.

PENSAUKEN FORMATION (included in Tpb)

DESCRIPTION: Sand, yellow to dark-reddish-brown (due to iron oxide), cemented, and extensively crossbedded; interbedded coarse gravel; boulders to 5 feet in size are common; gravel consists mostly of quartz, quartzite, and chert; thickness is at least 30 feet; reference section is at Turkey Hill, 2.4 miles south of Morrisville, Bucks County.

BEDDING: Well bedded; crossbedded.

FRACTURING: Crudely fractured; breaks are widely spaced, vertical, and open.

WEATHERING: Deeply weathered.

TOPOGRAPHY: Terrace remnant at an altitude of between 60 and 80 feet above sea level, parallel to the Delaware River.

DRAINAGE: Good surface drainage; locally may be poor, causing water to ''pond,'' although this is usually due to high water table.

POROSITY AND PERMEABILITY: High porosity and permeability.

GROUNDWATER: Generally an important source of groundwater in southeastern Bucks County; yields as much as 7,000 gal/min.

EASE OF EXCAVATION: Easy.

CUT-SLOPE STABILITY: Good to poor; maintains steep slope for short period of time; weathers rapidly.

FOUNDATION STABILITY: May be good; special work, including some replacement, compaction, and drainage facilities, may be necessary.

CONSTRUCTION MATERIALS: Good source of sand and gravel.

PETERS CREEK SCHIST (Xpc)

DESCRIPTION: Fine-grained, finely laminated, chlorite-sericite (mica) schist containing numerous thin beds of quartzite; quartzitic layers are interleaved with layers of mica; estimated to be 2,000 feet thick; type section is along Peters Creek at Peach Bottom, Lancaster County.

BEDDING: Thin; steeply dipping in most places.

FRACTURING: Cleavage has a platy pattern; well developed; highly abundant; displays an even regularity; very closely spaced; open and

steeply dipping. Joints are mostly irregular, poorly formed, widely spaced, steeply dipping, and open.

WEATHERING: Moderately resistant; often highly weathered to a moderate depth, resulting in uneven, hackly, small-sized, plate-like rubble at the base of exposures; overlying mantle is thin.

TOPOGRAPHY: Undulating hills of medium relief; natural slopes are moderately steep and stable.

DRAINAGE: Good surface drainage.

POROSITY AND PERMEABILITY: Joints and cleavage provide a low secondary porosity; low permeability.

GROUNDWATER: Median yield is 20 gal/min; best yields are obtained from the fractured, weathered zone at top of bedrock; water levels show strong seasonal influence; water is usually soft; iron may be a problem.

EASE OF EXCAVATION: Moderately easy; unweathered rock is difficult; moderate drilling rate.

CUT-SLOPE STABILITY: Fair, in part due to partial disintegration when exposed to moisture for a relatively short time; where fairly steep cuts are made, maintenance is required; drainage maintenance may be necessary.

FOUNDATION STABILITY: Good; should be excavated to sound material.

CONSTRUCTION MATERIALS: Good source of fill; may be a source of expandable aggregate.

ROCK TEST DATA:
Permeability = 0.1 ft/day (unweathered)
20 ft/day (highly weathered and fractured)

REMARKS: Test data from Dames and Moore, Inc.

PINESBURG STATION FORMATION (Ops; included in Ob)

DESCRIPTION: Light- to medium-gray, laminated to banded dolomite; contains black chert nodules and white quartz rosettes; interbeds of medium-gray limestone; maximum thickness is about 300 feet; reference section is near the Western Maryland Railroad tracks where they pass under Interstate Route 81 near interchange 5, Franklin County.

BEDDING: Well bedded; thick.

FRACTURING: Joints are abundant; widely spaced; blocky pattern; vertical and open.

WEATHERING: Moderately resistant; slightly weathered to a shallow depth; blocky fragments result; overlying mantle varies in thickness.

TOPOGRAPHY: Forms gently rolling lowlands of low relief; slopes are low and stable.

DRAINAGE: Good subsurface drainage; little surface drainage.

POROSITY AND PERMEABILITY: Joint and solution openings provide a secondary porosity of low magnitude; low permeability.

GROUNDWATER: One of the poorer units in the carbonate rock sequence of Franklin and Cumberland Counties; average yield is about 15 gal/min.

EASE OF EXCAVATION: Difficult; disposal or breakup of large blocks may be a problem; chert lenses may slow the fast drilling rate.

CUT-SLOPE STABILITY: Good; will maintain vertical cuts.

FOUNDATION STABILITY: Good; solution cavities should be investigated.

CONSTRUCTION MATERIALS: Good source of road material, riprap, building stone, embankment facing, and fill.

PITTSBURGH COAL (SEE MONONGAHELA GROUP)

PLEASANT HILL FORMATION (Ꞓph)

DESCRIPTION: Fine-grained, dark-gray limestone at top and argillaceous, sandy, and micaceous limestone and some calcareous shale at base; oolitic and fossiliferous; about 600 feet thick; type section is at Pleasant Hill Church, 1 mile northwest of Henrietta, Blair County.

BEDDING: Well bedded; thick bedded at top; thin-bedded basal unit.

FRACTURING: Moderately well developed joints; moderately abundant; moderate distance between fractures; open and steeply dipping.

WEATHERING: Moderately resistant; slightly weathered to a shallow depth; small- to medium-sized, flat, rectangular fragments and blocks result; the mantle-bedrock interface is characterized by pinnacles; mantle varies in thickness from 0 to over 40 feet.

TOPOGRAPHY: Rolling valley of low relief; gentle slopes are stable.

DRAINAGE: Good surface and subsurface drainage.

POROSITY AND PERMEABILITY: Joint and solution openings provide a secondary porosity of low to moderate magnitude; low to high permeability.

GROUNDWATER: Median yield (domestic wells) is 10 gal/min; yields far in excess of this are possible; quality is fair to good.

EASE OF EXCAVATION: Difficult; bedrock pinnacles are a special problem; fast drilling rate.

CUT-SLOPE STABILITY: Good; may be only fair in calcareous shale.

FOUNDATION STABILITY: Good; should be thoroughly investigated for solution openings.

CONSTRUCTION MATERIALS: Top part of formation is good source of road material; entire formation is good source of fill.

POCONO FORMATION (Mp; included in MDpr)

DESCRIPTION: Light- to olive-gray, fine- to medium-grained, crossbedded sandstone, siltstone, and conglomerate; conglomerate at base is composed of abundant rounded, white quartz pebbles as large as 3 inches in diameter; where conglomerate exists in middle of formation it is used to divide the unit into an upper member (Mount Carbon Member) and a lower member (Beckville Member); maximum thickness is in excess of 1,700 feet; reference section is on east bank of Lehigh River and in Jim Thorpe, Carbon County.

BEDDING: Well developed; thin to thick; crossbedding is common.

FRACTURING: Joints are well developed; moderately to highly abundant; regular; moderately to closely spaced; open and mostly steeply dipping to vertical.

Barbours sandstone, lower Pocono Formation.

WEATHERING: Highly resistant; breaks into large blocks; overlying mantle is thin.

TOPOGRAPHY: Forms high, rough ridges, crests of mountains, and hogbacks; natural slopes are steep and stable.

DRAINAGE: Surface drainage is good.

POROSITY AND PERMEABILITY: Interstitial porosity and secondary porosity give unit a high effective porosity; moderate to low permeability.

GROUNDWATER: Median yield is 40 gal/min; high iron may be a quality problem; soft water.

EASE OF EXCAVATION: Difficult; moderate to slow drilling rate.

CUT-SLOPE STABILITY: Good; rockfalls occur where bedding and joint surfaces intersect and rock is steeply dipping toward the cut; condition would be aggravated by a very steep vertical cut.

FOUNDATION STABILITY: Good.

CONSTRUCTION MATERIALS: Good source of building stone, embankment facing, road material, and riprap.

ROCK TEST DATA:
Permeability = 0 to 8 ft/day (slightly weathered shale)
0 to 29 ft/day (weathered and fractured shale)
0 to 38 ft/day (sandstone)

REMARKS: Test data from SCS.

PORT EWEN SHALE (included in Drc)

DESCRIPTION: Medium-dark-gray limy siltstone and shale; fossiliferous; laminated; about 150 feet thick; reference section is about 0.8 mile north of Tocks Island in the Delaware River, at the Middle Smithfield-Smithfield Township boundary, Monroe County.

BEDDING: Irregularly bedded and laminated; thick.

FRACTURING: Cleavage is well developed; joints are poorly developed; irregularly spaced, in most places having a wide distance between fractures; nearly vertical; open.

WEATHERING: Moderately resistant; moderately weathered to a moderate depth; small, tabular to pencil-shaped fragments result; overlying mantle is moderately thick.

TOPOGRAPHY: Flanks of ridges of medium relief; natural slopes are steep and stable.

DRAINAGE: Good surface drainage.

POROSITY AND PERMEABILITY: Joint-, bedding-, and cleavage-plane openings provide a secondary porosity of moderate magnitude; moderate permeability.

GROUNDWATER: Yields of greater than 100 gal/min are possible; water is moderately hard.

EASE OF EXCAVATION: Difficult; fast drilling rate.

CUT-SLOPE STABILITY: Fair; relatively rapid disintegration of shale and talus accumulation.

FOUNDATION STABILITY: Good; should be excavated to sound bedrock.

CONSTRUCTION MATERIALS: Good source of random fill.

POTTSVILLE GROUP (IPp; included in IPap)

DESCRIPTION: Light- to dark-gray, fine-grained to coarsely conglomeratic sandstone; subordinate amounts of gray shale, siltstone, limestone, coal, and underclay occur; includes Olean and Sharon conglomerates of northwestern Pennsylvania; locally, minable coals and commercially valuable high-alumina clay are present. The Pottsville Group includes those rocks in western Pennsylvania that are correlative with the Pottsville rocks of the Anthracite region in eastern Pennsylvania. Thickness varies from approximately 80 to 270 feet.

BEDDING: Generally well developed; sandstone and siltstone are crossbedded in many places; ranges from a fraction of an inch in shale to several feet in sandstone.

Topography of the Pottsville Group.

FRACTURING: Jointing and faulting are important. Joints are moderately well formed; distribution is moderate to high; spacing is wide to moderate in sandstone, close in shale; patterns are mostly regular; open and vertical. Subsidence fractures may be encountered in connection with underground clay and coal mining.

WEATHERING: Variable, reflecting rock type; sandstone is highly to moderately resistant; overlying mantle is thin; sandstone breaks into medium to large blocks and in places disintegrates to grains.

TOPOGRAPHY: Forms crests, flanks of ridges, and other breaks in topography; steep natural slopes are stable.

DRAINAGE: Surface drainage is good.

POROSITY AND PERMEABILITY: Variable, depending on lithology; sandstone has high to moderate effective porosity; low effective porosities are common in other rock types; moderate to low permeability.

GROUNDWATER: Median yield is 50 gal/min; sandstone and limestone provide highest yields, which may exceed 300 gal/min; iron content of water may be high; high topographic position is unfavorable; where encountered more than 100 feet below major drainage level, may contain salt water.

EASE OF EXCAVATION: Excavation of sandstone and conglomerate is difficult; other rock types are moderately easily excavated; moderate drilling rate.

Pottsville Group, Homewood Sandstone.

CUT-SLOPE STABILITY: Fair; undercutting in shale and underclay under thick sandstone units causes rockfalls and slumping; drainage maintenance may be needed.

FOUNDATION STABILITY: Good, except on or above underclay, which will deform under load when wet; underground coal and clay mines that have possible roof subsidence will need special study.

CONSTRUCTION MATERIALS: Good source of road material and fill, building stone, riprap, embankment facing, and refractory clay.

ROCK TEST DATA:
Permeability = 0 to 32 ft/day

REMARKS: Test data from SCS; field determination.

POTTSVILLE GROUP (ANTHRACITE REGION) (IPp)

DESCRIPTION: Includes three formations, in descending order: *Sharp Mountain Formation*—fine- to very coarse grained sandstone, shale, and siltstone containing plant debris and coals; distinctive conglomerate at base contains pebbles and cobbles that reach a maximum diameter of 8 inches; crossbedded; ripple marks; about 315 feet thick; reference section is along crest of Sharp Mountain, Lebanon County. *Schuylkill Formation*—light- to dark-gray sandstone, siltstone, shale, and conglomerate; plant debris is present in shale and coarse-grained sandstone; about 50 percent of member is conglomerate and conglomeratic sandstone; a basal conglomerate contains pebbles up to 3 inches in diameter; four persistent coals are present; maximum thickness is about 700 feet; reference section is on crest of Sharp Mountain, south of Middleport, Schuylkill County. *Tumbling Run Formation*—light- to dark-gray, olive-gray, and greenish-gray sandstone, siltstone, conglomerate, and shale; pebbles in upper beds are sparse; 55 percent of rock unit is conglomerate and conglomeratic sandstone that is concentrated in middle and lower parts; pebbles and cobbles reach a maximum diameter of 8 inches; poorly sorted; pebbles and cobbles are highly fractured; contains six anthracite beds; maximum thickness is 600 feet; reference section is along Pa. Route 924 north of Shenandoah, Schuylkill County.

BEDDING: Well bedded; massive in sandstone and conglomerate; thin to thick bedded in shale and siltstone.

FRACTURING: In sandstone and conglomerate, joints are well developed, have a blocky pattern, are widely spaced, and occur in vertical and horizontal sets; wide-open fractures are common.

WEATHERING: Highly resistant; conglomerate breaks into medium to large blocks, and in places disintegrates to a pebbly gravel and sand; cementation of sandstone and conglomerate is weak to moderate; mantle is thin.

Pottsville Group, Sharp Mountain Formation.

TOPOGRAPHY: Sharp Mountain Formation is the principal "ridge former"; formations, in general, underlie the crests of ridges, hogbacks, and the upper slopes of the region; natural slopes are steep and stable.

DRAINAGE: Good surface drainage.

POROSITY AND PERMEABILITY: Primary and secondary porosity of moderate magnitude; moderate permeability.

GROUNDWATER: Yields greater than 30 gal/min are common; reported yields range from 5 to 150 gal/min; good quality water; poor topographic position throughout much of outcrop area.

EASE OF EXCAVATION: Difficult; in highly weathered sandstone and conglomerate, moderately easy; slow drilling rate.

CUT-SLOPE STABILITY: Fair; undercutting in shale and coal under thick beds of sandstone and conglomerate causes rockfalls and slumping; drainage-diversion channels may be needed.

FOUNDATION STABILITY: Good; may need to be excavated to sound bedrock.

CONSTRUCTION MATERIALS: Good source of random fill.

POXONO ISLAND FORMATION (included in DSop and Sdp)

DESCRIPTION: Limy, light-olive-gray to green, silty and sandy shale, olive-green dolomite, and minor thin interbeds of fine-grained, limy sandstone and siltstone; maximum thickness is approximately 800 feet; reference section is along Pennsylvania side of Delaware River opposite Poxono Island, Monroe County.

BEDDING: Well bedded; laminated to thin.

FRACTURING: Joints and cleavage are well developed; highly abundant; irregular spacing, ranging from less than 2 inches to more than 2 feet; joints are open to width of 10 mm.

WEATHERING: Moderately resistant; moderately weathered to a moderate depth; small- to medium-sized, platy fragments result; overlying mantle is thin to moderately thick.

TOPOGRAPHY: Base of ridges of medium relief; natural slopes are steep and stable.

DRAINAGE: Good surface drainage.

POROSITY AND PERMEABILITY: Joint-, bedding-, and cleavage-plane openings provide a secondary porosity of moderate to high magnitude; moderate permeability.

GROUNDWATER: Yields of more than 160 gal/min are possible; water is moderately hard.

EASE OF EXCAVATION: Moderately easy; should be rippable where steeply dipping; fast drilling rate.

CUT-SLOPE STABILITY: Fair; shale disintegrates relatively rapidly.

FOUNDATION STABILITY: Good; should be excavated to sound bedrock.

CONSTRUCTION MATERIALS: Good source of random fill.

QUARTZ FANGLOMERATE (Trfq)

DESCRIPTION: Coarse conglomerate containing rounded cobbles and boulders of quartzite, sandstone, quartz, and some metarhyolite in a matrix of red sand; thickness is unknown; reference section is near Arendtsville, Adams County.

BEDDING: Poorly bedded; massive.

FRACTURING: Joints have an irregular pattern; poorly formed; widely spaced; steeply dipping and open.

WEATHERING: Rarely exposed as consolidated rock; deeply weathered; disintegration of matrix "cement" is rapid; thick mantle is composed of angular to subrounded fragments of quartz, sandstone, and quartzite.

TOPOGRAPHY: Moderately dissected semicircular hills having a scallop-like edge leading away from the base of South Mountain.

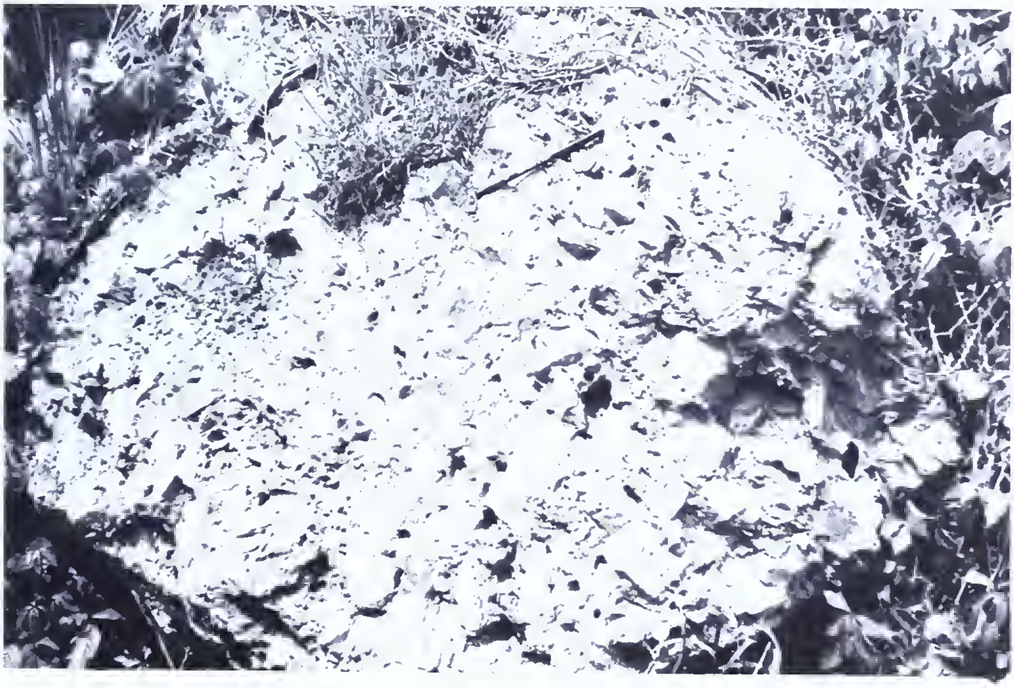
DRAINAGE: Good surface drainage.

POROSITY AND PERMEABILITY: Joints provide a secondary porosity of low magnitude; low permeability.

GROUNDWATER: Median well yield is 11 gal/min for nondomestic wells; maximum well yield of greater than 195 gal/min has been reported; generally of satisfactory quality for most purposes.

EASE OF EXCAVATION: Weathered mantle is easy to excavate; consolidated rock is difficult; quartz cobbles and boulders slow the drilling rate.

CUT-SLOPE STABILITY: Poor; sand matrix disintegrates rapidly.



FOUNDATION STABILITY: Good; should be excavated to hard, dense rock.

CONSTRUCTION MATERIALS: Good source of road material and fill, and possibly a source of decorative stone.

QUARTZ MONZONITE AND QUARTZ MONZONITE GNEISS (gqm)

DESCRIPTION: Medium grained, light to dark gray; composed of quartz and feldspar; also contains biotite, which imparts an irregular gneissic banding to the rock; reference section is in the railroad cut north of Christiana, Lancaster County.

BEDDING: None.

FRACTURING: Joints have an irregular pattern; poorly formed; widely to moderately spaced; nearly vertical and open.

WEATHERING: Highly resistant; slightly weathered to a shallow depth; loose surface material appears as large, isolated boulders; overlying mantle is thin.

TOPOGRAPHY: Uplands of low relief and rolling surface; natural slopes are gentle and stable.

DRAINAGE: Good surface drainage.

POROSITY AND PERMEABILITY: Little primary porosity; joints provide a low secondary porosity; low permeability.

GROUNDWATER: Median yield is 20 gal/min; highest yields may be obtained from fractured, weathered zone at top of bedrock; static water levels show strong seasonal influence; water is usually soft and of good quality.

EASE OF EXCAVATION: Difficult; slow drilling rate.

CUT-SLOPE STABILITY: Good.

FOUNDATION STABILITY: Good; should be excavated to sound bedrock.

CONSTRUCTION MATERIALS: Good source of riprap, embankment facing, and fill.

REEDSVILLE FORMATION (Or)

DESCRIPTION: Dark-gray shale containing thin sandy to silty shale interbeds; fossiliferous at top; at least 1,000 feet thick; type section is at Reedsville, Mifflin County.

BEDDING: Moderately well bedded; thin.

FRACTURING: Joints have a seamy to platy pattern; well developed and highly abundant; variably spaced, having a close distance between fractures; open and steeply dipping.

WEATHERING: Slightly resistant; moderately to highly weathered to a moderate to deep depth; weathering results in loose rubble containing individual fragments that are pencil-like in shape to rectangular plates; mantle is thin.

TOPOGRAPHY: Rolling valleys of medium relief; natural slopes are moderate and stable.

DRAINAGE: Good surface drainage.

POROSITY AND PERMEABILITY: Joint-, fault-, and bedding-plane openings provide a secondary porosity of low magnitude; low permeability.

GROUNDWATER: Median yield is 15 gal/min; most favorable well sites are in upland stream valleys; fracture openings decrease in number and size as depth increases; presence of some iron and hydrogen sulfide may cause water-quality problems.

EASE OF EXCAVATION: Moderately easy; slight rebound may be a special problem; fast drilling rate; sandy shale interbeds slow the drilling rate.

CUT-SLOPE STABILITY: Fair, due to disintegration when exposed to moisture for a relatively short time.

FOUNDATION STABILITY: Good; should be excavated to sound material.

CONSTRUCTION MATERIALS: Good source of road material and fill.

RICEVILLE SHALE (included in MDbr, MDcr, MDsr, and MDbv)

DESCRIPTION: Consists primarily of light-gray shale separated by thin layers of siltstone and fine-grained sandstone; fossiliferous; approximately 80 feet thick; reference section is in extreme southern part of Erie County.

BEDDING: Mostly well developed; generally less than 2 inches thick; flaggy and platy.

FRACTURING: Well developed; closely spaced in shale and siltstone; platy pattern in most places; open and steeply dipping to vertical.

WEATHERING: Shale disintegrates rapidly when exposed to moisture; results in small, platy, irregularly shaped fragments; sandstone and siltstone break up into small blocks; mantle is variable; thick glacial deposits may overlie rock unit.

TOPOGRAPHY: Forms much of the upland area in southern Erie County; bedrock topography may be masked by glacial material.

DRAINAGE: Surface drainage is moderate to good; may be poor where overlying glacial material is thick.

POROSITY AND PERMEABILITY: Secondary porosity predominates; some primary porosity in siltstone and sandstone; moderate to low effective porosity and permeability.

GROUNDWATER: Generally a good aquifer; median yield is 15 gal/min; in Erie County yields range from 2 to 40 gal/min.

EASE OF EXCAVATION: Moderately difficult; drilling rate is fast.

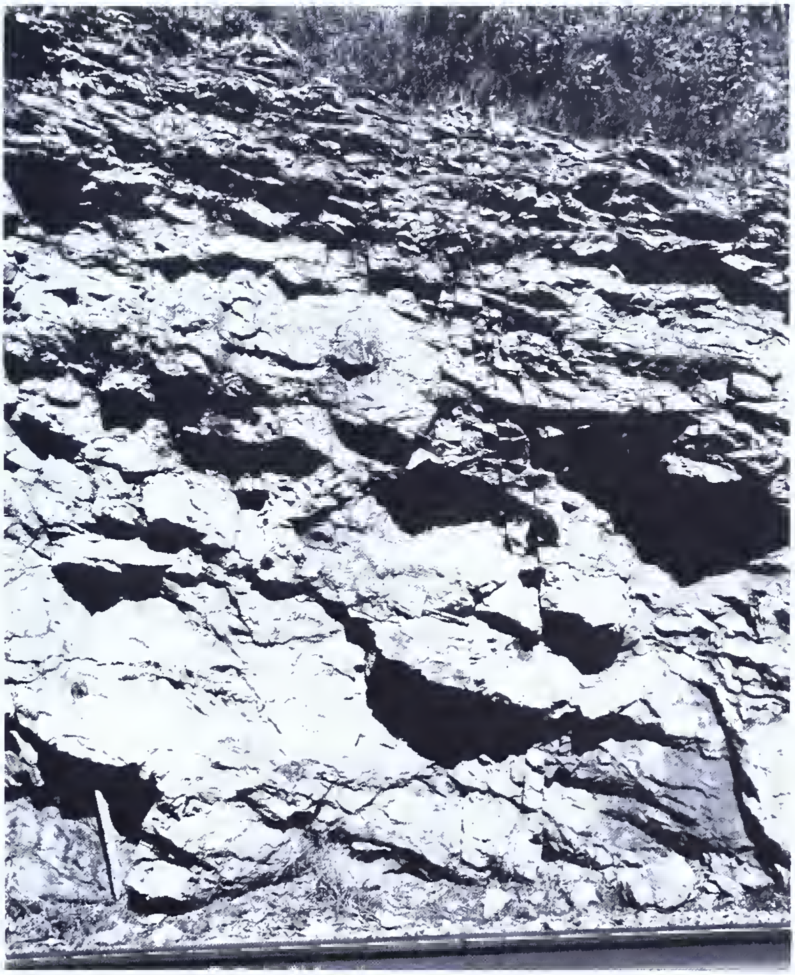
CUT-SLOPE STABILITY: Shale disintegrates rapidly; undercutting of thin, resistant siltstone and sandstone may cause poor-quality slopes and result in rockfalls; drainage maintenance may be required.

FOUNDATION STABILITY: Good; should be excavated to sound bedrock.

CONSTRUCTION MATERIALS: Good source of fill.

RICHLAND FORMATION (Єr)

DESCRIPTION: Gray, finely crystalline dolomite interbedded with medium-gray, oolitic limestone, chert, calcarenite, and conglomerate; approximately 1,300 feet thick; reference section is along railroad tracks one-fourth mile east of Richland, Lebanon County.



BEDDING: Well bedded; thick.

FRACTURING: Joints have a blocky pattern; well developed; moderately to highly abundant; regularly spaced, having a moderate distance between fractures; open and steeply dipping.

WEATHERING: Moderately resistant; slightly weathered to a shallow depth; decomposition results in medium-sized, blocky fragments; overlying mantle is thin in most places; interface between bedrock and mantle is characterized by pinnacles.

TOPOGRAPHY: Undulating valley of low relief; natural slopes are gentle and stable.

DRAINAGE: Good subsurface drainage; little surface drainage.

POROSITY AND PERMEABILITY: Solution channels produce a secondary porosity of low to moderate magnitude; low to moderate permeability.

GROUNDWATER: In Lebanon Valley, median yield is 125 gal/min; in Lancaster Valley, formation is only a fair source for small public supply (31 percent of wells studied have yields greater than 25 gal/min).

EASE OF EXCAVATION: Difficult; bedrock pinnacles are a special problem; moderate to slow drilling rate; numerous sandstone beds and chert lenses slow the drilling rate.

CUT-SLOPE STABILITY: Good; stable in vertical cuts.

FOUNDATION STABILITY: Good; a thorough investigation for solution cavities should be undertaken.

CONSTRUCTION MATERIALS: Good source of road material, riprap, building stone, embankment facing, and fill.

RICKENBACH FORMATION (Ori; included in Ob)

DESCRIPTION: Gray, very fine to coarsely crystalline, laminated dolomite; dark-gray chert in irregular beds, stringers, and nodules; bands of quartz and quartz-sand grains occur in lower half; thickness of at least 350 feet is present; reference section is along railroad tracks on west side of borough of Richland, Lebanon County.

BEDDING: Well bedded; thick.

FRACTURING: Joints have a blocky pattern; moderately to well developed; moderately abundant; regularly spaced, having a moderate dis-

tance between fractures; both a steeply dipping set and a gently dipping set are present; most are open but some are filled with calcite.

WEATHERING: Moderately resistant; slightly weathered to a shallow depth; small to large, blocky fragments result; overlying mantle is variable in thickness, in most places greater than 5 feet; bedrock pinnacles are characteristic.

TOPOGRAPHY: Flat to rolling valleys of low relief; gentle and stable natural slopes.

DRAINAGE: Good subsurface drainage; minor surface drainage.

POROSITY AND PERMEABILITY: Joint and solution-channel openings provide a secondary porosity of low to moderate magnitude; high permeability.

GROUNDWATER: Yields greater than 100 gal/min are common; industrial and public supplies of groundwater are available.

EASE OF EXCAVATION: Difficult; bedrock pinnacles are a special problem; moderate to fast drilling rate; chert beds and lenses and quartz-sand slow the drilling rate.

CUT-SLOPE STABILITY: Good; intersection of joint and bedding surfaces may create a problem if depth of cut is extreme.

FOUNDATION STABILITY: Good; should be investigated thoroughly for solution cavities.

CONSTRUCTION MATERIALS: Good source of road material, riprap, building stone, embankment facing, and fill.

RIDGELEY FORMATION (included in Drc and DSop)

DESCRIPTION: In eastern Pennsylvania, white to very light gray quartz sandstone and fine-grained pebble conglomerate; fossiliferous; maximum thickness is about 50 feet; reference section is at road level on the east side of the Pennsylvania Turnpike, Northeast Extension, at West Bowmans, Carbon County.

BEDDING: Poorly bedded; massive.

FRACTURING: Joints are well developed; moderately to highly abundant; regularly to irregularly spaced and open.

WEATHERING: Poorly resistant; deeply weathered; moderate to fast disintegration to sand and small boulders (less than 6 inches long); weathered rock surfaces commonly display protruding pebbles.

TOPOGRAPHY: Base of steep slopes and low ridges; natural slopes are stable.

DRAINAGE: Good surface drainage.

POROSITY AND PERMEABILITY: Joint-plane openings provide a secondary porosity of low to moderate magnitude; moderate permeability.

GROUNDWATER: Yields to 100 gal/min have been reported; outcrop area is narrow and recharge is usually very limited.

EASE OF EXCAVATION: Difficult; degree and depth of weathering are a major factor; the greater the amount of weathered, friable rock the easier to excavate; drilling rate is slow.

CUT-SLOPE STABILITY: Fair to good depending on the amount of rock disintegration by weathering.

FOUNDATION STABILITY: Good when excavated to sound, fresh bedrock; deep weathering may be a special problem.

CONSTRUCTION MATERIALS: Good source of sand.

RIDGELEY SANDSTONE (SEE OLD PORT FORMATION, RIDGELEY MEMBER)

ROCHESTER FORMATION (SEE MIFFLINTOWN FORMATION)

ROCKDALE RUN FORMATION (Orr; included in Ob)

DESCRIPTION: Very light gray, finely laminated, fine-grained limestone; pink to brown lenses of chert; a few dolomite beds; white quartz rosettes near top of formation; estimated to be 2,000 to 2,500 feet thick; reference section is north of Trindle Road at Locust Point, Cumberland County.

BEDDING: Medium bedded in lower third of formation; thick bedded in upper two thirds.

FRACTURING: Joints have a blocky pattern; moderately well developed; moderately abundant; regularly spaced; moderate distance between fractures; open and steeply dipping.

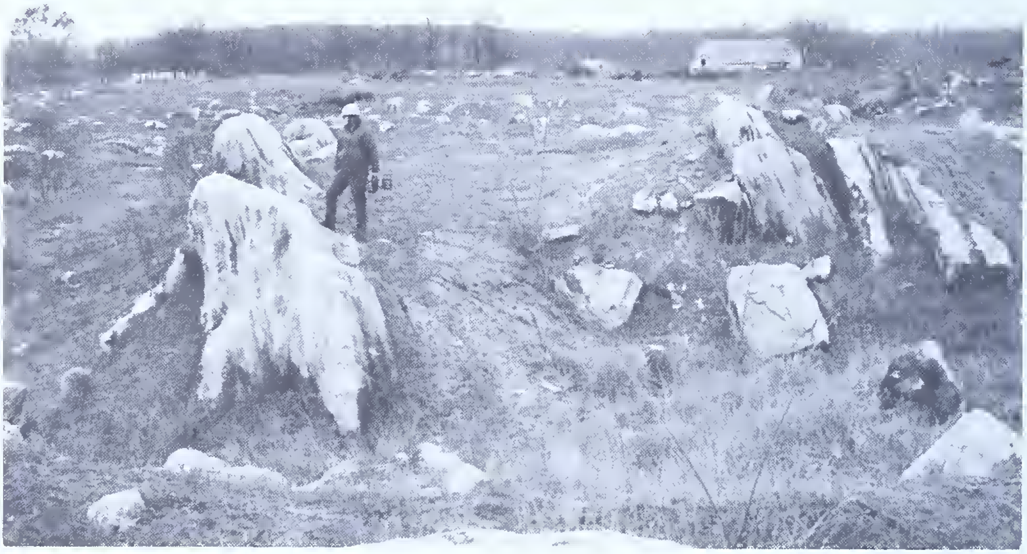
WEATHERING: Moderately resistant; moderately weathered to a deep depth; irregular and block-shaped fragments result from prolonged weathering; interface between bedrock and mantle is characterized by pinnacles.

TOPOGRAPHY: Rolling lowland; natural slopes are gentle and stable.

DRAINAGE: Good subsurface drainage; little surface drainage.

POROSITY AND PERMEABILITY: Fractures and solution channels provide a secondary porosity of moderate to high magnitude; low to moderate permeability.

GROUNDWATER: Yields range from in excess of 1,000 gal/min to 45 gal/min in 75 percent of all wells drilled; good for public supplies.



EASE OF EXCAVATION: Difficult; bedrock pinnacles may be a problem; chert and quartz lenses may slow the fast drilling rate.

CUT-SLOPE STABILITY: Good; should be investigated for solution openings and local intense pinnacle development.

CONSTRUCTION MATERIALS: Good source of coarse aggregate, agricultural lime, and building stone.

ROCKWELL FORMATION (MDr; included in MDpr)

DESCRIPTION: Buff-colored, fine- to medium-grained, crossbedded, argillaceous sandstone; includes some carbonaceous shale and a few conglomerate beds; maximum thickness is about 550 feet; named for rocks in Rockwell Run, Morgan County, West Virginia.

BEDDING: Well developed; moderate to thick; crossbedding is common.

FRACTURING: Joints are well developed; moderately abundant; regular; moderately spaced; open and steeply dipping to vertical.

WEATHERING: Highly resistant; breaks into large- to medium-sized blocks; mantle is thin.

TOPOGRAPHY: Forms high, rough ridges, mountain crests, and hogbacks; natural slopes are steep and stable.

DRAINAGE: Good surface drainage.

POROSITY AND PERMEABILITY: Primary porosity and secondary porosity are present; may have a high effective porosity; high permeability.

GROUNDWATER: May be an excellent aquifer; wells yielding in excess of 300 gal/min have been reported; topographic position will adversely affect yield; occasional high iron; overall quality is usually good; soft water.

EASE OF EXCAVATION: Difficult.

CUT-SLOPE STABILITY: Good; rockfalls may occur where bedding and joints intersect and rock is steeply dipping toward cut.

FOUNDATION STABILITY: Excellent.

CONSTRUCTION MATERIALS: Good source of fill, embankment facing, and riprap.

RONDOUT FORMATION (included in DSop)

DESCRIPTION: Medium-dark- to light-gray shale, limy shale, and clayey limestone (upper part); dolomite in middle part; sandy and clayey fossiliferous limestone at base; mud cracks are common; approximately 40 feet thick; reference section is along Pennsylvania side of Delaware River opposite Tocks Island, Monroe County.

BEDDING: Well bedded; thin to thick.

FRACTURING: Joints are well developed; regularly spaced, having a wide distance between fractures; open.

WEATHERING: Moderately resistant; moderately weathered to a moderate depth; small to large blocky fragments are present in talus at base of outcrop; talus is in thick accumulations in some areas; overlying mantle may be thick.

TOPOGRAPHY: High bluffs along Delaware River; ridge slopes of medium relief; natural slopes are stable in fresh rock; weathered talus slopes are unstable.

DRAINAGE: Good surface drainage.

POROSITY AND PERMEABILITY: Joint-plane, bedding-plane, and solution openings provide a secondary porosity of high magnitude; high permeability.

GROUNDWATER: Yields of 160 gal/min or more should be obtainable; water is moderately hard to very hard.

EASE OF EXCAVATION: Moderately difficult; moderate drilling rate.

CUT-SLOPE STABILITY: Good; minor rockfalls due to undercutting of shale under limestone.

FOUNDATION STABILITY: Good; talus and thick mantle may be a special problem; should be excavated to sound bedrock.

CONSTRUCTION MATERIALS: Good source of random fill and riprap; has been quarried for agricultural lime.

ROSE HILL FORMATION (included in Sc and DSkc)

DESCRIPTION: Light-olive-gray shale, some siltstone, and two grayish-red to reddish-black sandstone units; upper shale contains interbedded limestone; thickness is 947 feet; reference section is on northeast side of U. S. Route 22–322 from 1.7 to 2.8 miles north of Millerstown square, Perry County.

BEDDING: Well bedded; mostly fissile to thin; some medium beds.

FRACTURING: Joints are highly developed and have close to moderate spacing; nearly perpendicular to bedding and open from 5 to 10 mm.

WEATHERING: Moderately to highly resistant; interbedded sandstone is the most resistant; moderately weathered to a shallow depth; overlying mantle is thin; weathered material is shaly to blocky, less than 1 inch to 2 feet in diameter.

TOPOGRAPHY: Forms hills of moderate relief and lower slopes of mountain ridges; resistant sandstone beds underlie prominent secondary ridges; natural slopes are moderate to fairly steep and stable.

DRAINAGE: Good surface drainage.

POROSITY AND PERMEABILITY: Joint- and bedding-plane openings provide a moderate secondary porosity and permeability.

GROUNDWATER: Aquifer potential is low to moderate; reported yields range from 5 to 30 gal/min from wells 60 to 300 feet deep; reported median hardness is 5 grains per gallon; median specific conductance is 200 micromhos at 25 °C.

EASE OF EXCAVATION: Intermediate to moderately difficult; sandstone beds are difficult; drilling rate is fast to moderate in shale and siltstone, and slow in sandstone.

CUT-SLOPE STABILITY: Good to fair; steep cuts can be maintained; some rockfall and accumulation of shale-chip rubble at toe of slopes can be expected.

FOUNDATION STABILITY: Good; soil and weathered rock should be excavated to sound rock.

CONSTRUCTION MATERIALS: Lower shaly member is ranked fair for expanded lightweight aggregate and structural clay products; good source of random fill; iron ore associated with sandstone beds has been mined.

ST. PAUL GROUP (Osp)

DESCRIPTION: Buff-colored, magnesium limestone containing numerous layers of chert; high-calcium limestone in part; 580 feet thick at reference section in the northwest corner of the Mechanicsburg Naval Supply Depot, Cumberland County.

BEDDING: Well bedded; most beds are fissile to flaggy; a few are thick bedded.

FRACTURING: Most joints have a blocky pattern; some have a platy pattern; moderately well developed; moderately to highly abundant; fairly regularly spaced, having a moderate distance between fractures; most fractures are open, but some are filled with calcite; steeply dipping to vertical.

WEATHERING: Moderately resistant; slightly weathered to a shallow depth; medium-sized blocks commonly result; overlying mantle is moderately thick; bedrock-mantle interface is characterized by pinnacles in most places.

TOPOGRAPHY: Rolling valley of low relief; natural slopes are gentle and stable.

DRAINAGE: Good subsurface drainage; poor surface drainage; sinkholes are common.

POROSITY AND PERMEABILITY: Joint and solution openings provide a secondary porosity of moderate to high magnitude; high permeability.

GROUNDWATER: Median yield is 25 gal/min; some wells encounter solution openings and have very large yields; water is relatively hard.

EASE OF EXCAVATION: Difficult; bedrock pinnacles are a special problem; moderate drilling rate.

CUT-SLOPE STABILITY: Good; steeply dipping beds inclined toward the roadway require moderate to gentle cuts.

FOUNDATION STABILITY: Good; should be excavated to sound material and should be thoroughly investigated for possible solution cavities.

CONSTRUCTION MATERIALS: Good source of road materials and fill; may be high in calcium and suitable for fluxstone.

ROCK TEST DATA:
Specific gravity = 2.69 to 2.71
Absorption = 0.24 to 0.26%

REMARKS: Test data from PDT.

SALONA FORMATION (included in Ocn and Ocl)

DESCRIPTION: Dark-gray to black limestone; laminated; medium- to coarse-grained; fossiliferous; black chert nodules; approximately 170 feet thick; reference section is in New Enterprise Lime and Stone Company quarry at Roaring Spring, Blair County.

BEDDING: Well bedded; mostly fissile to flaggy; a few thick beds.

FRACTURING: Most joints have a blocky pattern; some have a platy pattern; moderately well developed; moderately to highly abundant; fairly regular, having a moderate distance between fractures; most fractures are open, but some are filled with calcite; steeply dipping to vertical.

WEATHERING: Moderately resistant; slightly weathered to a shallow depth; shaly limestone beds appear moderately weathered to a deeper depth; medium-sized blocks commonly result; shaly units weather to small, pencil-like, flat fragments; overlying mantle is moderately thick; bedrock-mantle interface is characterized by pinnacles in most places.

TOPOGRAPHY: Rolling valley of low relief; natural slopes are gentle and stable.

DRAINAGE: Good subsurface drainage; poor surface drainage; sinkholes are common.

POROSITY AND PERMEABILITY: Joint and solution openings provide a secondary porosity of moderate to high magnitude; moderate to low permeability.

GROUNDWATER: Median yield is 50 gal/min; hydrogen sulfide is sometimes present; water is sometimes hard.

EASE OF EXCAVATION: Difficult; bedrock pinnacles are a special problem; moderate drilling rate.

CUT-SLOPE STABILITY: Good; shaly limestone beds are susceptible to moisture and have only fair, short-term stability; steeply dipping beds inclined toward the roadway have only fair stability.

FOUNDATION STABILITY: Good; should be excavated to sound material and should be thoroughly investigated for possible solution cavities.

CONSTRUCTION MATERIALS: Good source of road material and fill.

ROCK TEST DATA:
Specific gravity = 2.70
Absorption = 0.32%

REMARKS: Test data from PDT.

SCHAEFFERSTOWN FORMATION (included in Ꞓms)

DESCRIPTION: Medium-light-gray to medium-gray limestone; finely crystalline; distinct shaly bands and fine laminations; maximum thickness is 300 feet; reference section is in a small quarry and adjacent outcrops in the village of Schaefferstown, Lebanon County.

BEDDING: Well bedded; thick to flaggy; shaly interbeds as thick as 8 inches occur.

FRACTURING: Joints have a blocky pattern; well developed; moderately abundant; fairly regularly spaced; open and vertical.

WEATHERING: Moderately resistant; slightly weathered to a shallow depth; rectangular blocks and irregularly shaped fragments result; thickness of overlying mantle is variable; interface between bedrock and soil is flat in most areas.

TOPOGRAPHY: Rolling valley of low relief; natural slopes are gentle and stable.

DRAINAGE: Good subsurface drainage; little surface drainage; sinkholes may be present.

POROSITY AND PERMEABILITY: Joint- and bedding-plane openings provide a secondary porosity of moderate to high magnitude; highly permeable.

GROUNDWATER: Yields in excess of 100 gal/min are common from depths of less than 300 feet; hard water.

EASE OF EXCAVATION: Difficult; fast drilling rate.

CUT-SLOPE STABILITY: Good; no slope failures have been reported or seen.

FOUNDATION STABILITY: Good; investigation for solution cavities should be undertaken.

CONSTRUCTION MATERIALS: Good source of random fill.

SCHERR FORMATION (Ds)

DESCRIPTION: Olive-gray to greenish-gray sandstone and siltstone, medium-gray shale, and greenish-gray mudrock; fossiliferous; tan weathering; maximum thickness is about 1,900 feet; reference section is along a tributary to Wills Creek, approximately 1.2 miles southwest of Hyndman, Bedford County.

BEDDING: Well bedded; sandstone is thin to thick bedded in 1-inch to 1.5-foot layers; shale is smooth to hackly bedded.

FRACTURING: Joints are well developed; one set is steeply dipping and another is nearly horizontal; closely spaced and open.

WEATHERING: Moderately resistant; moderate depth of weathering; fragments are small and blocky and have a rough surface; mantle is thin.

TOPOGRAPHY: Gently rolling uplands; natural slopes are stable; steep and stable where dissected by surface streams.

DRAINAGE: Good surface drainage.

POROSITY AND PERMEABILITY: Joint- and bedding-plane openings provide a secondary porosity of low magnitude; low permeability.

GROUNDWATER: Yields are adequate for domestic supply; average reported yields are about 15 gal/min; iron content may be high.

EASE OF EXCAVATION: Moderately difficult to difficult; fast to moderate drilling rate.

CUT-SLOPE STABILITY: Fair to good; where thin bedded and highly fractured, only fair.

FOUNDATION STABILITY: Good; should be excavated to sound material.

CONSTRUCTION MATERIALS: Good source of random fill.

SCHOHARIE FORMATION (included in Dbe)

DESCRIPTION: Very fine to coarse-grained, gray to olive-gray, hard siltstone; fossiliferous; thickness is about 25 feet; reference section is along east side of Northeast Extension of Pennsylvania Turnpike at West Bowmans, Carbon County.

BEDDING: Well bedded; massive.

FRACTURING: Joints have a blocky pattern; highly developed; moderately abundant; moderately spaced; open.

WEATHERING: Moderately weathered to a shallow depth; weathered fragments are blocky to platy; overlying mantle is moderately thick.

TOPOGRAPHY: Flanks of low ridges; natural slopes are fairly steep and stable.

DRAINAGE: Good surface drainage.

POROSITY AND PERMEABILITY: Joint- and bedding-plane openings provide a moderate secondary porosity; moderate permeability.

GROUNDWATER: Wells yield up to 73 gal/min; water is soft and of good quality.

EASE OF EXCAVATION: Difficult; drilling rate is moderate to fast.

CUT-SLOPE STABILITY: Good to fair; rockfalls may occur where siltstone is highly fractured.

FOUNDATION STABILITY: Good; should be excavated to sound bedrock.

CONSTRUCTION MATERIALS: Good source of random fill.

SERPENTINITE (Xs)

DESCRIPTION: Magnesium-rich rock derived from pyroxenite and peridotite; usually green in color and can be fibrous.

BEDDING: None.

FRACTURING: Joints have a platy to irregular pattern; moderately developed; highly abundant; closely spaced and irregular; open joints are characteristic but some are filled with quartz; mostly steeply dipping.

WEATHERING: Moderately resistant; moderately weathered, in most places to a shallow depth, resulting in irregular, hackly, broken masses of medium-sized fragments; thin overlying mantle.

TOPOGRAPHY: Undulating hills of low relief having gentle, stable slopes.

DRAINAGE: Good surface drainage.

POROSITY AND PERMEABILITY: Secondary porosity of low magnitude; low permeability.

GROUNDWATER: Median well yield is 20 gal/min; groundwater is usually obtained from fractured, weathered zone at top of bedrock; static water levels show strong seasonal influence.

EASE OF EXCAVATION: Difficult; slow drilling rate; numerous quartz veins contribute to slow drillability.

CUT-SLOPE STABILITY: Fair to good, due to fracturing.

FOUNDATION STABILITY: Excellent; should be excavated to sound material.

CONSTRUCTION MATERIALS: Good source of road material, riprap, and fill.

ROCK TEST DATA:
Permeability = 1 to 615 ft/day (weathered rock)
0 to 0.5 ft/day (solid rock)

REMARKS: Test data on serpentine from SCS; field determination.

SETTERS QUARTZITE (Xsq)

DESCRIPTION: Light gray; weathered outer portion is light brown to dark brown; coarse grained; micaceous layers; maximum thickness is 150 feet; reference section is in small quarry at Avondale, Chester County.

BEDDING: Well bedded; flaggy.

FRACTURING: Joints have a seamy to platy pattern; well formed; moderately abundant; widely spaced; steeply dipping and open.

WEATHERING: Highly resistant; slightly weathered to a shallow depth; medium-sized, flat fragments result from weathering; long, continued weathering may result in complete disintegration to sand-sized particles; overlying mantle is very thin.

TOPOGRAPHY: Rolling hills of medium relief; natural slopes are moderate and stable.

DRAINAGE: Good surface drainage.

POROSITY AND PERMEABILITY: Secondary porosity of low magnitude; low permeability.

GROUNDWATER: Median yield is 20 gal/min; best yields can be obtained from fractured, weathered zone at top of bedrock; water levels show strong seasonal influence; water is usually soft and of good quality.

EASE OF EXCAVATION: Difficult except where highly weathered; up to several feet below surface may be moderately easy; slow drilling rate.

CUT-SLOPE STABILITY: Good; where steeply dipping, rock should not be undercut.

FOUNDATION STABILITY: Good; should be excavated to sound material.

CONSTRUCTION MATERIALS: Good source of road material, riprap, embankment facing, fill, and building stone.

SHADYGROVE FORMATION (Ꞓsg)

DESCRIPTION: Light-gray to pinkish-gray, finely crystalline limestone; fossiliferous; abundant nodules of brown chert; few sandstone beds; few beds of laminated dolomite; estimated maximum thickness of 1,000 feet; reference section is along Pa. Route 16 at the village of Shady Grove, Franklin County.

BEDDING: Well bedded; thick to massive.

FRACTURING: Joints have a blocky pattern; moderately well developed; moderately abundant; regularly spaced, having a moderate distance between fractures; open and steeply dipping.

WEATHERING: Moderately resistant; slightly to moderately weathered to a shallow depth; irregularly shaped to medium-sized blocks result from long-term weathering; pinnacle interface between bedrock and soil.

TOPOGRAPHY: Gently rolling lowlands; natural slopes are gentle and stable.

DRAINAGE: Good subsurface drainage; little surface drainage.

POROSITY AND PERMEABILITY: Joint openings and solution channels create a secondary porosity; low-magnitude porosity and permeability.

GROUNDWATER: A median sustained yield of 26 gal/min is estimated for this formation.

EASE OF EXCAVATION: Difficult; bedrock pinnacles are a special problem; thin sandstone interbeds and chert nodules slow the drilling rate.

CUT-SLOPE STABILITY: Good; maintains nearly vertical cuts.

FOUNDATION STABILITY: Good; should be thoroughly investigated for caverns.

CONSTRUCTION MATERIALS: Good source of fill.

SHAWANGUNK FORMATION (Ss)

DESCRIPTION: Light- to dark-gray, fine- to very coarse grained sandstone and conglomerate containing thin shale interbeds; crossbedded; tightly cemented. Includes four members, in descending order: *Tammany Member*—conglomerate and sandstone; *Lizard Creek Member*—sandstone and red and green shale; *Minsi Member*—sandstone and conglomerate; and *Weiders Member*—conglomerate. Maximum thickness is 1,600 feet; reference section is in the Delaware Water Gap, Monroe County.

BEDDING: Bedding is variable; may be obscured by crossbedding; thick in most places.

FRACTURING: Well-developed joints having blocky patterns; moderately to highly abundant; moderately spaced in regular sequence; open and steeply dipping to vertical.

WEATHERING: Highly resistant; slightly weathered to a shallow depth; weathers to irregular, medium to large blocks; in many places, forms large boulder fields downslope from outcrop; overlying mantle is very thin.

TOPOGRAPHY: High mountains and ridges; very high relief in rough terrain; natural slopes are stable and steep.

DRAINAGE: Good surface drainage.

POROSITY AND PERMEABILITY: Intergranular porosity in conglomerate; joint openings provide a small to moderate secondary porosity; low permeability.

GROUNDWATER: Median yield is 35 gal/min; may be a poor aquifer because of topographic position; often of excellent quality.

EASE OF EXCAVATION: Difficult; boulder fields on lower slopes beneath outcrop areas are a special problem; drilling rate is very slow.

CUT-SLOPE STABILITY: Good; can stand in vertical cuts if bedding is not steeply dipping toward cut.

FOUNDATION STABILITY: Good; excavate to sound bedrock.

CONSTRUCTION MATERIALS: Good source of road material, riprap, concrete aggregate, embankment facing, building stone, and silica for refractory brick.

SHENANGO FORMATION (Ms; included in Msc, Mbc, MDsr, and MDso)

DESCRIPTION: Upper part of formation is soft, medium- to dark-gray shale, medium-light-gray siltstone, and limy siltstone; lower part is fine-grained sandstone, light-gray to yellowish-gray, fossiliferous, cross-bedded, containing some interbedded dark- to medium-gray shale and siltstone; maximum thickness is about 190 feet; type section is along the Shenango River valley in south-central Delaware Township, Mercer County.

BEDDING: Well bedded; shale is fissile; sandstone is flaggy to massive with planar laminations; siltstone is thin.

FRACTURING: Joints are well formed in sandstone and poorly formed in shale; widely spaced; blocky pattern in sandstone; open and vertical.

WEATHERING: Shale is soft and easily eroded; sandstone and siltstone are more resistant; thin to moderate mantle thickness.

TOPOGRAPHY: In Mercer and Venango Counties, forms valleys of low relief, and swamps; natural slopes are gentle and stable; in Crawford County, forms high uplands having gentle to steep slopes.

DRAINAGE: Surface drainage is variable, ranging from fair to good; swamps are common.

POROSITY AND PERMEABILITY: Joints produce a secondary porosity of low to high magnitude depending on number and spacing of fractures and whether rock type is shale or sandstone; highly fractured sandstone has moderate porosity and permeability; shale is soft, contains very few fractures, and has low porosity and permeability.

GROUNDWATER: Shale yields little or no water to wells and has a median yield of less than 5 gal/min; sandstone of lower part of formation is a good aquifer, having an estimated optimum yield of 68 gal/min; locally high in iron at shallow depths.

EASE OF EXCAVATION: Shale is excavated moderately easily; sandstone is difficult; drilling rate is moderate to fast.

CUT-SLOPE STABILITY: Good to only fair where excessive undercutting of resistant sandstone occurs; undercutting is caused by rapid erosion of soft shale.

FOUNDATION STABILITY: Good; should be excavated to sound bedrock.

CONSTRUCTION MATERIALS: Good source of fill; sandstone may be source of embankment facing and building stone.

SHRIVER CHERT (included in Drc)

DESCRIPTION: In eastern Pennsylvania, white to orange chert, sandstone, conglomerate, and sandy limestone; fossiliferous; maximum thickness is about 75 feet; reference section is at the clay pits of the Universal Atlas Cement Company near Kunkletown, Monroe County.

BEDDING: Irregularly bedded; sometimes nodular; maximum bedding thickness is about 1 foot.

FRACTURING: Highly developed joints; most are regularly spaced, having a moderate to wide spacing; moderately abundant; most are open but some are filled with calcite or quartz.

WEATHERING: Moderately to poorly resistant; many sandstone and chert beds are highly disintegrated; deep leaching; red and brown iron staining is common; mantle thickness is variable.

TOPOGRAPHY: Low ridges of medium relief; natural slopes are stable.

DRAINAGE: Good surface drainage.

POROSITY AND PERMEABILITY: Joint- and bedding-plane openings provide a secondary porosity of low magnitude; low permeability.

GROUNDWATER: Yields are generally low, usually less than 5 gal/min; water is soft and of good quality.

EASE OF EXCAVATION: Where the chert and sandstone are highly weathered and leached, excavation is easy; difficult in fresh, unweathered bedrock; moderate to slow drilling rate.

CUT-SLOPE STABILITY: Fair to poor; high disintegration and deep leaching may account for poor stability.

FOUNDATION STABILITY: Excellent after removal of weathered rock; deep weathering may be a special problem.

CONSTRUCTION MATERIALS: Good source of random fill.

SNITZ CREEK FORMATION (€sc; included in €sb)

DESCRIPTION: Gray, medium- to coarsely crystalline dolomite; oolitic; sandstone interbeds; maximum thickness is approximately 500 feet; reference section is along Cornwall-Lebanon railroad tracks about 0.5 mile south of Midway, Lebanon County.

BEDDING: Well bedded; thick to massive.

FRACTURING: Joints have a blocky pattern; moderately well developed; moderately to highly abundant; regularly spaced, having a moderate distance between fractures; open and steeply dipping.

WEATHERING: Moderately resistant; slightly to moderately weathered to a shallow depth; irregularly shaped, medium-sized blocks result from prolonged weathering; interface between bedrock and mantle is characterized by pinnacles in most places..

TOPOGRAPHY: Rolling valleys of low relief; natural slopes are gentle and stable.

DRAINAGE: Good subsurface drainage; little surface drainage.

POROSITY AND PERMEABILITY: Primary porosity in the weathered portion; solution channels provide a secondary porosity of moderate to high magnitude; locally, a high porosity is encountered; moderate to high permeability.

GROUNDWATER: Median yield of wells in Lebanon Valley is 75 gal/min; in Lancaster Valley, a fair source for small public supply (38 percent of wells tested have yields greater than 25 gal/min).

EASE OF EXCAVATION: Difficult; bedrock pinnacles are a special problem; numerous sandstone beds slow the fast drilling rate.

CUT-SLOPE STABILITY: Fair in limy sandstone units that show rapid disintegration when exposed to moisture for a relatively short time; good in dolomite and sandy dolomite.

FOUNDATION STABILITY: Good; a thorough investigation for solution cavities should be undertaken.

CONSTRUCTION MATERIALS: Good source of road material, riprap, embankment facing, fill, and aggregate.

SNYDER FORMATION (included in Obl and Ocl)

DESCRIPTION: Medium- to medium-dark-gray, coarsely crystalline limestone containing limestone conglomerate beds; medium-dark-gray limestone containing numerous impure bands, which show mud cracks and ripple marks; medium-dark-gray, laminated, finely crystalline, dolomitic limestone; light-gray, very finely crystalline limestone; and medium-dark-gray, fine-grained, oolitic and ''mud pellet'' limestone; approximately 70 feet thick; reference section is in the Oak Hall quarry, Centre County.

BEDDING: Well bedded; platy to thick.

FRACTURING: Most joints have a blocky pattern; a few have a platy pattern; moderately well developed and moderately abundant; regularly spaced, having a moderate spacing; most are open but some are filled with calcite; steeply dipping.

WEATHERING: Moderately resistant; slightly weathered to a shallow depth; limestone weathers light olive gray; scattered pebbles weather almost white; dolomitic limestone weathers light tan with yellowish stain; oolites are not visible unless weathered.

TOPOGRAPHY: Rolling valley of low relief; natural slopes are gentle and stable.

DRAINAGE: Good subsurface drainage; poor surface drainage; sinkholes are common.

POROSITY AND PERMEABILITY: Joint and solution openings provide a secondary porosity of moderate to high magnitude; low to moderate permeability.

GROUNDWATER: Median yield is 50 gal/min; usually of excellent quality.

EASE OF EXCAVATION: Difficult; bedrock pinnacles may be a special problem; fast drilling rate.

CUT-SLOPE STABILITY: Good; steeply dipping beds inclined toward cut may have only fair stability.

FOUNDATION STABILITY: Good; should be thoroughly investigated for solution cavities.

CONSTRUCTION MATERIALS: Good source of fill.

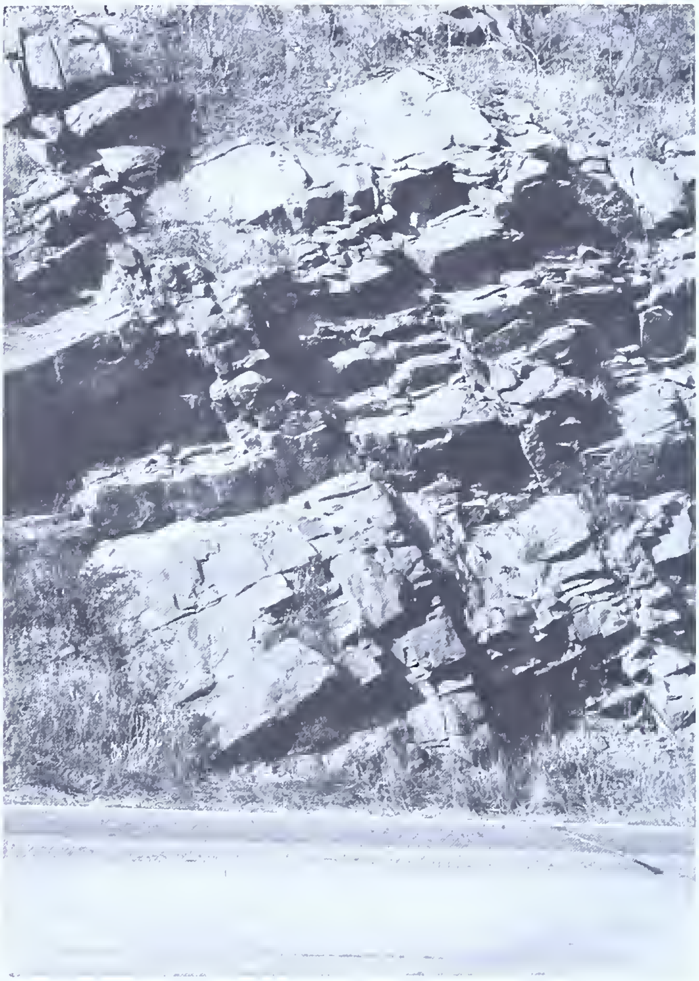
SPECHTY KOPF FORMATION (MDsk)

DESCRIPTION: Light- to olive-gray, fine- to medium-grained sandstone containing interbeds of olive-gray to dark-gray shale and siltstone; locally has grayish-red shale near top and conglomerate at base and in middle; contains minor thin coal and coalified plant fragments; up to 575 feet thick; reference section is in roadcut on U. S. Routes 11 and 15 on west side of Susquehanna River 0.4 mile south of road intersection at Mt. Patrick, Perry County.

BEDDING: Well bedded; planar bedding and some crossbedding; beds are 2 inches to 5 feet thick.

FRACTURING: Highly developed joints; irregular spacing, generally 2 inches to 3 feet; open 10 to 50 mm.

WEATHERING: Highly resistant; slightly weathered to a shallow to moderate depth; fragments are blocky to tabular, 1 inch to 10 feet in diameter; overlying mantle is thin to moderately thick in boulder colluvium on some slopes.



TOPOGRAPHY: Forms mountains of high relief; topographic expression is approximately 800 to 900 feet; natural slopes are moderate to steep and stable.

DRAINAGE: Good surface drainage.

POROSITY AND PERMEABILITY: Joint-, fault-, and bedding-plane openings provide a moderate to low secondary porosity and moderate permeability.

GROUNDWATER: Generally unproductive on ridge crests but favorable for development below ridge crests; median yield is 25 gal/min from wells between 40 and 350 feet deep; generally good quality; occasional high iron content; salt water may be found in deeper wells.

EASE OF EXCAVATION: Difficult; moderately difficult in shale; drilling rate is slow to moderate.

CUT-SLOPE STABILITY: Generally good; poor where cut slope parallels strike and dip of bedding; rockfall occurs in steep cuts, notably where sandstone overhangs easily eroded shale beds.

FOUNDATION STABILITY: Excellent after removal of unconsolidated mantle.

CONSTRUCTION MATERIAL: Quarried for crushed stone and aggregate for road construction; good source of riprap, rock protection, and rock fill.

STOCKTON FORMATION (Trs)

DESCRIPTION: Light-gray to buff, coarse-grained, arkosic sandstone; includes red to purplish-red sandstone, shale, and siltstone; maximum thickness is approximately 3,300 feet; reference section is north of Valley Forge along Schuylkill River and along railroad west of the river, Montgomery County.

BEDDING: Well bedded; thin to flaggy.

FRACTURING: Joints have a seamy to platy pattern; moderately developed; highly fractured; very closely spaced; vertical and open.

WEATHERING: Only slightly resistant; highly weathered to a moderate depth; very small, pencil-like, platy fragments result from rapid disintegration; overlying mantle is thin.

TOPOGRAPHY: Undulating valleys of low relief; natural slopes are stable.

DRAINAGE: Good surface drainage.

POROSITY AND PERMEABILITY: Primary porosity occurs in weathered portion; joint- and bedding-plane openings provide a secondary porosity in unweathered rock; high to moderate total effective porosity and permeability.

GROUNDWATER: Average yield is 130 gal/min from arkosic sandstone and 20 gal/min from shale; good quality.

EASE OF EXCAVATION: Moderately easy; relatively fast drilling rate.

CUT-SLOPE STABILITY: Poor to fair, due to rapid disintegration when exposed to moisture for a relatively short time.

FOUNDATION STABILITY: Good; should be excavated to sound rock material; underdrainage may be required.

CONSTRUCTION MATERIALS: Good source of brick, floor tile, and sintered aggregate material; also a source of fill.

ROCK TEST DATA:
Compressive strength = 108 to 1,116 tons/ft^2

REMARKS: Test data from USBM.

STOCKTON FORMATION, CONGLOMERATE (Trsc)

DESCRIPTION: Gray, reddish-brown, and pale-orange coarse conglomerate, consisting chiefly of quartz cobbles and boulders in a poorly sorted sand matrix; maximum thickness is 2,700 feet; reference section is in railroad cut west of Bridgeport, Montgomery County.

BEDDING: Well bedded; flaggy to thick.

FRACTURING: Joints have a platy to blocky pattern; moderately developed; moderately fractured; vertical and open.

WEATHERING: Moderately resistant; moderately weathered to a moderate depth in a short period of time; overlying mantle is thin.

TOPOGRAPHY: Undulating hills of low relief; natural slopes are stable.

DRAINAGE: Good surface drainage.

POROSITY AND PERMEABILITY: Primary porosity; joint- and bedding-plane openings provide secondary porosity; moderate to high total effective porosity and permeability.

GROUNDWATER: Average reported yield is about 110 gal/min; good quality.

EASE OF EXCAVATION: Moderately easy in weathered portion; difficult in fresh rock at depth; drilling rate is slowed by quartz cobbles and boulders.

CUT-SLOPE STABILITY: Fair, due to relatively fast disintegration when exposed to moisture for a short period of time.

FOUNDATION STABILITY: Good; should be excavated to sound bedrock.

CONSTRUCTION MATERIALS: Good source of fill.

STONEHENGE FORMATION (Os; included in Ons and Ob)

DESCRIPTION: Gray, finely crystalline limestone and dark-gray laminated limestone; contains numerous flat-pebble breccia beds and shaly interbeds; maximum thickness is 1,500 feet; reference section is in small quarry east of the railroad crossing in Richland, Lebanon County.

BEDDING: Moderately well to well bedded; thin to flaggy.

FRACTURING: Joints have a seamy pattern; well developed to poorly developed; moderately abundant; moderate distance between fractures; open and steeply dipping to vertical.

WEATHERING: Moderately resistant; slightly weathered to a shallow depth; small- to medium-sized, flat, rectangular fragments result; overly-

ing mantle varies in thickness, and is greater than 80 feet thick in places; bedrock pinnacles are characteristic.

TOPOGRAPHY: Rolling valleys of low relief; gentle and stable natural slopes.

DRAINAGE: Good subsurface drainage; sinkholes are characteristic.

POROSITY AND PERMEABILITY: Joint and solution-channel openings provide a secondary porosity of low to moderate magnitude; high permeability.

GROUNDWATER: Median yield is 100 gal/min; highest yields are obtained from fractures and solution cavities; water is relatively hard.

EASE OF EXCAVATION: Difficult; bedrock pinnacles are a special problem; fast drilling rate.

CUT-SLOPE STABILITY: Mostly good; only fair where severely fractured.

FOUNDATION STABILITY: Good; should be excavated to sound bedrock and thoroughly investigated for solution openings.

CONSTRUCTION MATERIALS: Good source of road material, riprap, building stone, flagstone, embankment facing, and random fill.

ROCK TEST DATA:
Absorption = 0.24%
Specific gravity (bulk, saturated surface—dry) = 2.69

REMARKS: Test data from PDT.

STOUFFERSTOWN FORMATION (included in Os)

DESCRIPTION: Coarse-grained limestone; dark-gray siliceous seams that weather to a yellow-brown color; oolitic; bright-orange-weathering patches of dolomite one-half inch or less in diameter are a characteristic feature; edgewise conglomerate beds are typical; maximum measured thickness is 261 feet; type section is 1,200 feet east of the center of Chambersburg on U.S. Route 30, Franklin County.

BEDDING: Well bedded; thick to massive.

FRACTURING: Joints are locally well developed; wide spacing; generally filled with calcite and closed; one joint set is moderately to steeply dipping and one set is almost horizontal.

WEATHERING: Moderately resistant; slightly weathered to a shallow depth; siliceous seams are more resistant and weather in sharp relief to the limestone; overlying mantle varies in thickness; bedrock-mantle interface is sharp and pinnacled; soil contains dark-colored, hard, shaly chips.

TOPOGRAPHY: Continuous narrow ridge of low relief; steep to moderate, stable slopes.

DRAINAGE: Good subsurface drainage.

POROSITY AND PERMEABILITY: Joint and solution openings provide a secondary porosity of low magnitude; low permeability.

GROUNDWATER: Very little groundwater data exist; thought to be poorest yielding carbonate aquifer in south-central Pennsylvania; median sustained yield of less than 30 gal/min is likely.

EASE OF EXCAVATION: Difficult; large blocks may result; pinnacles may be a special problem.

CUT-SLOPE STABILITY: Fair; siliceous bands (seams) may cause rockfalls.

FOUNDATION STABILITY: Good; should be excavated to sound rock; slight possibility of solution cavities.

CONSTRUCTION MATERIALS: Good source of agricultural limestone and fill.

TIOGA BENTONITE (SEE MARCELLUS FORMATION)

TOMSTOWN FORMATION (Ꞓt)

DESCRIPTION: Upper part is medium-dark-gray to dark-gray, medium-crystalline dolomite, oolitic and laminated; lower part is medium-light-gray to pinkish-gray, finely crystalline, sandy dolomite; maximum thickness is approximately 1,000 feet; reference section is at Tomstown, Franklin County.

BEDDING: Moderately well bedded; massive.

FRACTURING: Joints have a blocky pattern and are moderately to well developed; moderately abundant; irregularly spaced, having a wide distance between fractures; open and steeply dipping.

WEATHERING: Moderately resistant; slightly to moderately weathered to a shallow depth; breakup of the rock results in large blocks; overlying mantle is thin, and pinnacles may characterize the interface between mantle and bedrock.

TOPOGRAPHY: Undulating valley of low to medium relief; natural slopes are gentle to moderately steep and stable.

DRAINAGE: Good surface drainage; little subsurface drainage.

POROSITY AND PERMEABILITY: Joint and solution openings provide a secondary porosity of low magnitude; low permeability.

GROUNDWATER: Median yield is 23 gal/min; water is relatively hard.

EASE OF EXCAVATION: Difficult; bedrock pinnacles may be a special problem; moderate drilling rate may be expected.

CUT-SLOPE STABILITY: Good.

FOUNDATION STABILITY: Good; solution cavities and bedrock pinnacles should be thoroughly investigated.

CONSTRUCTION MATERIALS: Good source of road material, riprap, aggregate, building stone, embankment facing, and fill.

TONOLOWAY FORMATION (included in DSkt, DSkm, and DSkc)

DESCRIPTION: Medium-gray laminated limestone containing interbedded zones of medium-dark-gray to light-olive-gray shale and siltstone;

400 feet thick at type section on lower slopes of Tonoloway Ridge, Washington County, Maryland.

BEDDING: Well bedded; flaggy to thick.

FRACTURING: Joints have a platy pattern and, rarely, a blocky pattern; moderately developed; moderately to highly abundant; regularly spaced, having a moderate to close distance between fractures; open and steeply dipping.

WEATHERING: Moderately resistant; moderately weathered to a moderate to shallow depth; results in small- to medium-sized, irregularly shaped blocks; mantle is thin in most places; bedrock pinnacles may exist.

TOPOGRAPHY: Rolling hills of medium relief; natural slopes are moderate and stable.

DRAINAGE: Good surface drainage; minor subsurface drainage.

POROSITY AND PERMEABILITY: Solution channels and joint- and bedding-plane openings provide a secondary porosity of moderate magnitude; moderate to low permeability.

GROUNDWATER: Median yield is 30 gal/min; water quality decreases with increasing depth; water may be high in dissolved solids; hard; some iron problems.

EASE OF EXCAVATION: Difficult; bedrock pinnacles are a special problem; fast drilling rate.

CUT-SLOPE STABILITY: Good; if there is local intense fracturing and the cut is deep, stability may be only fair.

FOUNDATION STABILITY: Good; thorough investigation for solution openings should be undertaken; should be excavated to sound material.

CONSTRUCTION MATERIALS: Good source of road material, riprap, embankment facing, and fill.

ROCK TEST DATA:
Specific gravity = 2.72 to 2.73
Absorption = 0.25 to 0.50%
0.20 to 0.96%

REMARKS: Test data from USCE and PDT.

TRENTON GRAVEL (Qt)

DESCRIPTION: Gray to pale-reddish-brown, very gravelly sand; interbedded crossbedded sand and clay-silt layers; ''Cape May Formation'' of earlier workers; thickness is about 30 feet; reference section is in pit at Penn Valley, Bucks County.

BEDDING: Well bedded; crossbedded.

FRACTURING: None apparent.

WEATHERING: Deeply weathered; contains weathered gravel of granite, sandstone, gneiss, siltstone, and quartzite.

TOPOGRAPHY: Low-lying gravels at about 20 feet above sea level; occurs in Delaware River valley.

DRAINAGE: Good surface drainage.

POROSITY AND PERMEABILITY: High porosity and permeability.

GROUNDWATER: Generally a good aquifer; yields may be in excess of 1,000 gal/min.

EASE OF EXCAVATION: Easy.

CUT-SLOPE STABILITY: Poor.

FOUNDATION STABILITY: Poor; special work may be necessary, including replacement, compaction, and drainage facilities.

CONSTRUCTION MATERIALS: Good source of sand.

TRIMMERS ROCK FORMATION (Dtr)

DESCRIPTION: Light-gray to olive, fine-grained sandstone and siltstone with olive to gray shale interbeds; maximum thickness is about 3,000 feet; type section is at Trimmers Rock, 1.5 miles east of Newport, Perry County.

BEDDING: Well developed; massive to flaggy.

FRACTURING: Joints are well developed; moderately to closely spaced; steeply dipping; blocky and platy pattern; regularly spaced.

WEATHERING: Moderately to slightly resistant; moderately weathered to a moderate depth; medium to small blocks result from disintegration of sandstone beds; small, flat, plate-like fragments accumulate at base of shale units; overlying mantle is moderate to thick, composed mostly of glacial till in the northeast.

TOPOGRAPHY: Rolling ridges of medium relief; natural slopes are steep and stable.

DRAINAGE: Good surface drainage.

POROSITY AND PERMEABILITY: Joint- and bedding-plane openings provide a secondary porosity of moderate magnitude; moderate to low permeability.

GROUNDWATER: Median yield is 30 gal/min; may be high in total dissolved solids; very soft water; may contain hydrogen sulfide.

EASE OF EXCAVATION: Moderately difficult; moderate drilling rate may be expected.

CUT-SLOPE STABILITY: Fair in siltstone and shale; good in sandstone.

FOUNDATION STABILITY: Good; should be excavated to sound material.

CONSTRUCTION MATERIALS: Good source of road material and fill.

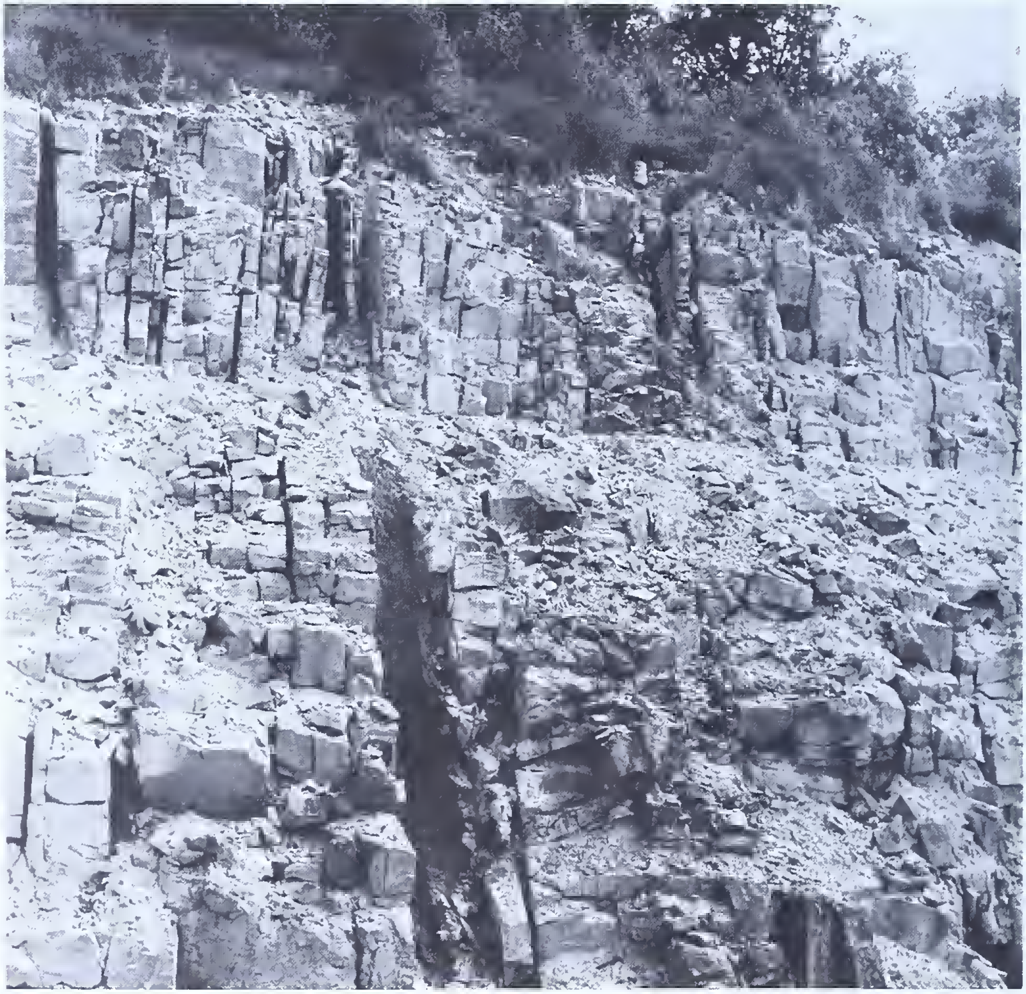
TUSCARORA FORMATION (St)

DESCRIPTION: Sandstone and quartzite; fine to coarse grained; white, sometimes red and green; tough; firmly cemented; crossbedded; conglomeratic in part; includes interbedded red and nonred sandstone (Castanea Member) at top; maximum thickness is 1,500 feet; type section is on Tuscarora Mountain, at the Juniata-Perry County boundary.

BEDDING: Bedding is variable; may be obscured by crossbedding; mostly thick.

FRACTURING: Well-developed joints in a blocky pattern; moderately to highly abundant; moderately spaced in regular sequence; open and steeply dipping to vertical.

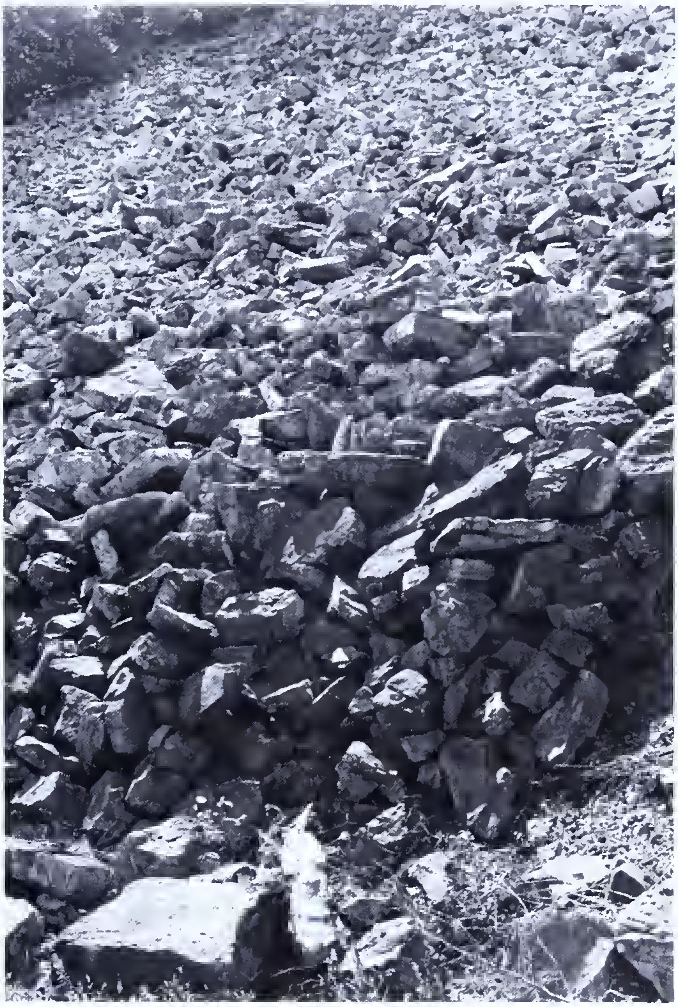
WEATHERING: Highly resistant; slightly weathered to a shallow depth; weathers to irregular, medium to large blocks; in most places, forms large boulder fields downslope from outcrop; overlying mantle is thin.



TOPOGRAPHY: High mountains and ridges; high relief in rough terrain; natural slopes are stable and steep.

DRAINAGE: Good surface drainage.

POROSITY AND PERMEABILITY: Intergranular porosity in conglomerate; joint openings provide a low to moderate secondary porosity; low permeability.



Talus slope in the Tuscarora Formation.

GROUNDWATER: Median yield is 23 gal/min; high topographic position is unfavorable for high yields; water quality is usually good; soft water.

EASE OF EXCAVATION: Difficult; boulder fields on lower slopes beneath outcrop areas are a special problem; drilling rate is slow.

CUT-SLOPE STABILITY: Good; if bedding is steeply dipping toward cut, fair.

FOUNDATION STABILITY: Good; excavate to sound bedrock.

CONSTRUCTION MATERIALS: Good source of road material, riprap, aggregate, embankment facing, building stone, and silica for refractory brick.

UPPER FREEPORT COAL (SEE ALLEGHENY GROUP)

VANPORT LIMESTONE (SEE ALLEGHENY GROUP)

VENANGO FORMATION (Dv; included in MDbv)

DESCRIPTION: Complex unit consisting of bluish-gray shale, light-gray siltstone, and gray sandstone; Panama Conglomerate and Woodstock Sandstone are the upper and lower key horizons in the formation; referred to as "Cattaraugus" by some geologists; 80 feet thick; named for exposures in Venango County.

BEDDING: Well developed in most places; thickness ranges from less than 1 foot (flaggy) to 4 feet in coarser beds; crossbedding is common; sedimentary features are common.

FRACTURING: Moderately well developed; closely spaced in shale and siltstone; commonly form a blocky or platy pattern; open and steeply dipping or vertical.

WEATHERING: Shale disintegrates rapidly when exposed to moisture, resulting in small, platy, triangular fragments; sandstone, siltstone, and conglomerate are moderately resistant, and break up into medium and large blocks; mantle is variable in thickness in glaciated areas of northwestern Pennsylvania.

TOPOGRAPHY: Plateaus of medium relief; natural slopes are stable at fairly steep angles.

DRAINAGE: Surface drainage is moderate to good; in glaciated regions, drainage is poor.

POROSITY AND PERMEABILITY: Interstitial porosity is low in coarser rocks; joint development creates a moderate total effective porosity; low permeability.

GROUNDWATER: Median yield is 7 gal/min; yields range from 0.2 to 90 gal/min; wells greater than 100 feet deep often encounter salt water; high iron content is sometimes a problem.

EASE OF EXCAVATION: Moderately difficult; relative drillability is moderate.

CUT-SLOPE STABILITY: Good in sandstone and conglomerate; fair in siltstone and shale, which disintegrate rapidly; undercutting of resistant coarser beds can cause poor-quality slopes and result in rockfalls; drainage maintenance is required.

FOUNDATION STABILITY: Good; shale and siltstone should be kept water free; must be excavated to sound bedrock.

CONSTRUCTION MATERIALS: Good source of brick raw material, aggregate, roof granules, and fill.

ROCK TEST DATA:
Unconfined compressive strength = 7,320 to 8,110 lb/in^2

REMARKS: Compressive strength data from John H. Robinson Engineering Inc.

VINTAGE FORMATION (Єv)

DESCRIPTION: Dark-gray, knotty, argillaceous dolomite having impure, light-gray marble at the base; maximum thickness is 650 feet; type section is in railroad cut 15 miles east of Lancaster, Lancaster County.

BEDDING: Moderately well bedded; massive.

FRACTURING: Joints have a blocky pattern; moderately to well developed; moderately abundant; irregularly spaced, having a wide distance between fractures; open and steeply dipping.

WEATHERING: Moderately resistant; slightly to moderately weathered to a shallow depth; breakup results in large blocks; overlying mantle is thin; pinnacles characterize the interface between mantle and bedrock.

TOPOGRAPHY: Undulating valley of low to medium relief; natural slopes are gentle to moderately steep and stable.

DRAINAGE: Good surface drainage; little subsurface drainage.

POROSITY AND PERMEABILITY: Joint and solution openings provide a secondary porosity of moderate magnitude; low permeability.

GROUNDWATER: Median yield is 30 gal/min; water is relatively hard.

EASE OF EXCAVATION: Difficult; bedrock pinnacles are a special problem; fast drilling rate.

CUT-SLOPE STABILITY: Good.

FOUNDATION STABILITY: Good; solution cavities and bedrock pinnacles should be thoroughly investigated.

CONSTRUCTION MATERIALS: Good source of road material, riprap, aggregate, building stone, embankment facing, and fill.

WARRIOR FORMATION (Ꞓw)

DESCRIPTION: Relatively pure, medium-gray limestone; grades to shaly limestone having thin sandy partings; some interbedded gray dolomite; some oolitic limestone; fossiliferous; edgewise conglomerate beds; maximum thickness is about 1,200 feet; reference section is at Williamsburg (Blair County), 25 miles southwest of Scotia.

BEDDING: Well bedded; thick.

FRACTURING: Joints are moderately well developed; moderately abundant; moderate distance between fractures; open and steeply dipping.

WEATHERING: Moderately resistant; slightly weathered to a shallow depth; small- to medium-sized, flat, rectangular fragments result; overlying mantle varies in thickness from 0 to more than 40 feet; bedrock pinnacles are present.

TOPOGRAPHY: Rolling valley of low relief; gentle to moderately steep slopes.

DRAINAGE: Good surface and subsurface drainage.

POROSITY AND PERMEABILITY: Joint and solution openings provide a secondary porosity of low to moderate magnitude; low to high permeability.

GROUNDWATER: Highest yields are from fractures and solution openings; yields greater than 100 gal/min may be realized; groundwater is relatively hard.

EASE OF EXCAVATION: Difficult; bedrock pinnacles are a special problem; fast drilling rate.

CUT-SLOPE STABILITY: Mostly good; only fair where fracturing is intense.

FOUNDATION STABILITY: Good; should be excavated to sound bedrock and thoroughly investigated for solution openings.

CONSTRUCTION MATERIALS: Good source of road material, riprap, flagstone, embankment facing, and random fill.

WASHINGTON FORMATION (Pw)

DESCRIPTION: Cyclic sequences of sandstone, limestone, shale, claystone, and some thin coal beds and underclay; most sandstone is light gray, medium grained, and crossbedded; limestone is gray and finely crystalline; some limestone is very argillaceous, containing interbedded dark-gray shale; claystone and shale are dark-gray; includes some red shale; base is at bottom of Washington coal; thickness varies from 160 to 234 feet; type area is in and near Washington, Washington County.

BEDDING: Moderately well developed in limestone and shale; may be obscured by crossbedding in sandstone; beds of sandstone tend to be thick and massive, whereas limestone is flaggy.

FRACTURING: Joints have a blocky pattern; well developed; closely spaced in finer grained rocks; irregular and moderately spaced in sandstone; vertical and open.

WEATHERING: Variable, depending on type of rock; limestone and sandstone are moderately resistant and depth of weathering is shallow; claystone, shale, and coal weather readily and cause rockfalls where they disintegrate rapidly under more resistant beds; overlying mantle varies from thin to moderate.

TOPOGRAPHY: A rough land surface of moderate to high relief; topography is noticeable for the exceptional number of small streams separated by short, narrow divides; normally, steep natural slopes are stable.

DRAINAGE: Surface drainage is fair to good; limited subsurface drainage may occur in limestone.

POROSITY AND PERMEABILITY: Limited primary porosity occurs in sandstone and siltstone; limestone is very dense and tight; secondary porosity is provided by joint development; low-magnitude porosity and permeability.

GROUNDWATER: Median yield is 15 gal/min; yields as high as 250 gal/min have been reported; many sandstone and limestone units provide sufficient water for domestic use; care should be taken in well construction to prevent contamination of water.

EASE OF EXCAVATION: Siltstone, shale, and coal are excavated easily; sandstone and limestone are difficult; occasional deep weathering will reduce excavation effort; drilling rate is fast.

CUT-SLOPE STABILITY: Fair; weaker rocks cause undercutting of resistant units, resulting in rockfalls, slumps, and landslides.

FOUNDATION STABILITY: Generally good; excavation to sound material is necessary; foundations should not be placed in or above underclay or claystone because these rocks tend to deform under load when wet; extra precautions are required when construction is planned over mined-out areas.

CONSTRUCTION MATERIALS: Good source of fill; unweathered sandstone is good source of riprap and embankment facing; limestone is suitable for chemical, agricultural, and building uses when clay content is not high.

ROCK TEST DATA:
Sandstone
Specific gravity = 2.13 to 2.17
Compressive strength ([lb/in^2] x 1000) = 8.3 to 9.9
Youngs modulus ([lb/in^2] x 10^6) = 1.01 to 1.34
Modulus of rigidity ([lb/in^2] x 10^6) = 0.51 to 0.61
Poissons ratio = 0.01 to 0.09

REMARKS: Test data from USBM.

WAYNESBORO FORMATION (Ꞓwb)

DESCRIPTION: Sandy dolomite, containing fine-grained to silt-sized quartz; interbanded limestone and dolomite; chert and white vein quartz are common; limestone is dark gray to very light gray; near the top, beds of dark-red to purple sandy shale, siltstone, and sandstone occur; maximum thickness is approximately 1,000 feet; type sections are near the town of Waynesboro in southern Franklin County.

BEDDING: Well bedded; massive to flaggy to thin bedded.

FRACTURING: Joints have a platy pattern; some have a blocky pattern; moderately fractured; moderate distance between fractures; steeply dipping and open.

WEATHERING: Moderately resistant; moderately to highly weathered to a moderate depth; platy to blocky fragments result; fragments of porous sandstone, chert, and vein quartz are common in mantle; thickness of mantle is variable.

TOPOGRAPHY: South of Waynesboro, terrain is composed of rolling ridges; to the north, it is a series of discontinuous hills.

DRAINAGE: Good subsurface drainage; minor surface drainage.

POROSITY AND PERMEABILITY: Joint and solution openings provide a secondary porosity of moderate magnitude; sandstone units have a primary porosity; permeability is moderate.

GROUNDWATER: Data available indicate a calculated median sustained yield of 172 gal/min; reported yields range from less than 1 to 400 gal/min.

EASE OF EXCAVATION: Moderately easy; difficult at depth in unweathered rock; fast drilling rate.

CUT-SLOPE STABILITY: Fair, due to disintegration when exposed to moisture.

FOUNDATION STABILITY: Good; should be excavated to sound material; should be investigated thoroughly for solution cavities.

CONSTRUCTION MATERIALS: Good source of fill.

WAYNESBURG FORMATION (PIPw)

DESCRIPTION: Cyclic sequence of sandstone, shale, limestone, siltstone, some claystone, and coal; limestone is gray, finely crystalline, argillaceous, locally nodular, and interbedded with claystone; sandstone is light gray, very fine to medium grained, and crossbedded; shale is gray and locally calcareous, and may be interbedded with siltstone and sandstone; siltstone is gray; thickness ranges from 100 to 245 feet; type area is Waynesburg, Greene County.

BEDDING: Generally well bedded; sandstone is thin to thick and has some crossbedding; limestone varies from well bedded to nodular; siltstone is thin; shale is thin and has poor to good fissility; claystone is poorly bedded.

FRACTURING: Joints have an irregular pattern; poorly formed; highly abundant; moderately to closely spaced; steeply dipping and open.

WEATHERING: Moderately resistant; highly weathered to a deep depth; small, irregularly shaped fragments result from weathering; overlying mantle is thin.

TOPOGRAPHY: Rough mountains of medium relief; natural slopes are steep and stable.

DRAINAGE: Good surface drainage.

POROSITY AND PERMEABILITY: Joints provide a secondary porosity of low magnitude.

GROUNDWATER: Wells should produce small supplies for domestic purposes; probably should not be drilled deeper than 200 feet for maximum yield; well sites must be carefully chosen; valleys, fault zones, and other fracture zones are the most favorable sites.

EASE OF EXCAVATION: Difficult, except where highly fractured, in which case excavation is moderately easy; moderate to slow drilling rate.

CUT-SLOPE STABILITY: Only fair, due to rapid disintegration when exposed to moisture for a relatively short time.

FOUNDATION STABILITY: Good; should be excavated to sound material.

CONSTRUCTION MATERIALS: Good source of fill; unweathered sandstone is good source of riprap and embankment facing and is locally quarried for road construction and building stone; limestone is suitable for chemical, agricultural, and building uses where clay content is not high; shale has potential for brick and lightweight aggregate.

WEVERTON FORMATION (included in Ꞓwl)

DESCRIPTION: Gray to purplish-gray, coarse-grained, feldspathic quartzite and quartzose conglomerate, containing rounded pebbles; maximum thickness is 1,200 feet; type section is at Weverton, Washington County, Maryland.

BEDDING: Crudely bedded and thick to massive.

FRACTURING: Joints have an irregular pattern; poorly formed; highly abundant; moderately to closely spaced; steeply dipping and open.

WEATHERING: Moderately resistant; highly weathered to a deep depth; small, irregularly shaped fragments result; overlying mantle is thin.

TOPOGRAPHY: Rough mountains of medium relief; natural slopes are steep and stable.

DRAINAGE: Good surface drainage.

POROSITY AND PERMEABILITY: Joints provide a secondary porosity of low magnitude; low permeability.

GROUNDWATER: Median yield is 24 gal/min; highest yields are obtained from fractured, weathered zone at top of bedrock; water levels show strong seasonal influence; water is soft and of good quality; iron is sometimes a problem.

EASE OF EXCAVATION: Difficult except where highly fractured, in which case excavation is moderately easy; moderate to slow drilling rate.

CUT-SLOPE STABILITY: Only fair, due to rapid disintegration when exposed to moisture for a relatively short time.

FOUNDATION STABILITY: Good; should be excavated to sound material.

CONSTRUCTION MATERIALS: Good source of fill.

WILLS CREEK FORMATION (Swc; included in Swm, DSkm, and DSkc)

DESCRIPTION: Greenish-gray shale containing local limestone and sandstone zones; red shale and siltstone occur in lower part of formation; thickness is in excess of 650 feet; reference section is along Pa. Route 274 west of Cisna Run, Perry County.

BEDDING: Moderately well bedded; fissile to thin.

FRACTURING: Joints have a seamy to platy pattern; well developed; highly abundant; regularly spaced, having a very close distance between fractures; open and gently to steeply dipping.

WEATHERING: Slightly resistant; highly weathered to a moderate depth; small, flat, irregularly shaped fragments result; overlying mantle is thin.

TOPOGRAPHY: Undulating hills of low relief; natural slopes are gentle and stable.

DRAINAGE: Good surface drainage.

POROSITY AND PERMEABILITY: Joint- and bedding-plane openings provide a secondary porosity of low magnitude; low permeability.

GROUNDWATER: Median yield is 32 gal/min; quality decreases with increasing depth; hydrogen sulfide has been noted in some wells; iron may be a problem.

EASE OF EXCAVATION: Moderately easy; fast drilling rate.

CUT-SLOPE STABILITY: Fair, due to disintegration when exposed to moisture for a relatively short time.

FOUNDATION STABILITY: Good; should be excavated to sound material.

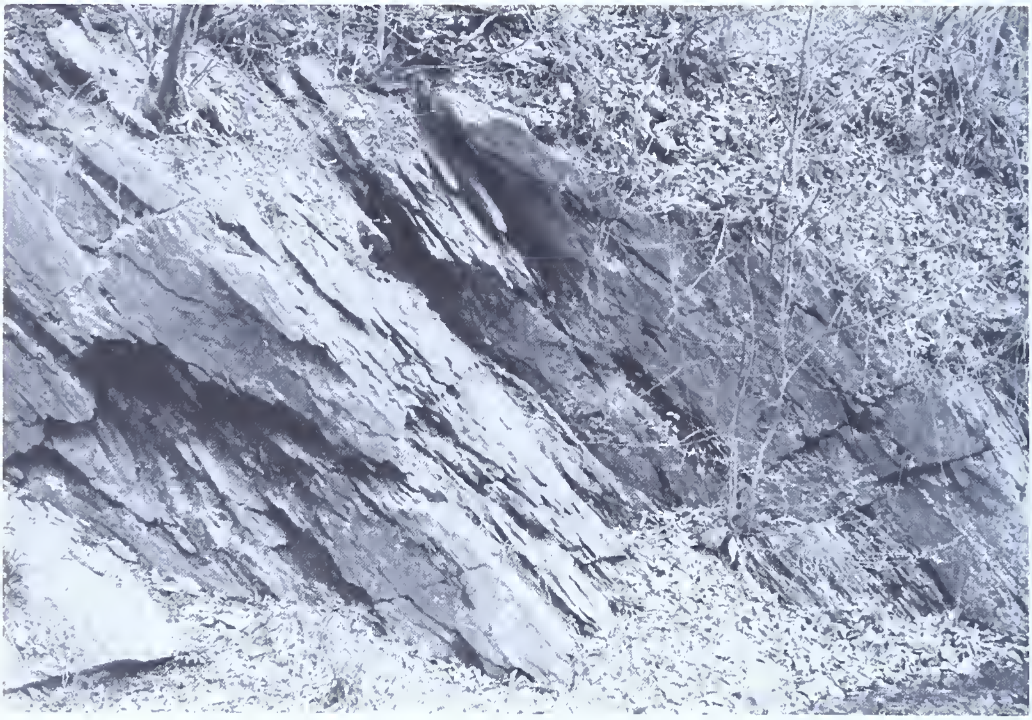
CONSTRUCTION MATERIALS: Good source of road material and fill; possible source of common brick material.

ROCK TEST DATA:
Equivalent permeability = 0.2 to 27.4 cm/sec × 10^{-4}
Water of plasticity = 18%
Drying shrinkage = 1%

REMARKS: Permeability data from USCE; other data from USBM.

WISSAHICKON FORMATION (includes Xwc, Xwm, Xww, Xwv, and Xw)

DESCRIPTION: Includes the following members: *albite-chlorite schist* — typically a phyllite, composed chiefly of quartz, feldspar, muscovite, and chlorite; *oligoclase-mica schist* — more coarsely crystalline than albite-chlorite schist and excessively micaceous;



Wissahickon Formation, albite-chlorite schist.

feldspar is more abundant in the oligoclase-mica schist; *Marburg Schist* — gray-green mica-chlorite-quartzite schist; *metavolcanics* — altered basaltic flows, green, schistose; *Wakefield Marble* — light gray and coarsely crystalline, containing flakes of graphite scattered throughout; estimated thickness of Wissahickon is 8,000 to 10,000 feet; reference sections are along railroad tracks on east side of Susquehanna River in southern Lancaster County.

BEDDING: Fissile to thin; steeply dipping in most places.

FRACTURING: Cleavage has a platy pattern; well developed; highly abundant; displays an even regularity; very closely spaced; open and steeply dipping. Joints are for the most part irregular, poorly formed, widely spaced, steeply dipping, and open.

WEATHERING: Moderately resistant; often highly weathered to a moderate depth, resulting in uneven, hackly, small-sized, plate-like rubble at base of exposure; overlying mantle is thin.

TOPOGRAPHY: Undulating hills of medium relief; natural slopes are moderately steep and stable.

DRAINAGE: Good surface drainage.

POROSITY AND PERMEABILITY: Joint and cleavage openings provide a low secondary porosity; low permeability.

GROUNDWATER: Median yield is 20 gal/min; highest yield can be obtained from fractured, weathered zone at top of bedrock; water levels show strong seasonal influence; water is usually soft and of good quality; iron can sometimes be a problem.

EASE OF EXCAVATION: Moderately easy; difficult in unweathered rock; moderate drilling rate.

CUT-SLOPE STABILITY: Fair, in part due to partial disintegration when exposed to moisture for a relatively short time; drainage maintenance may be required.

FOUNDATION STABILITY: Good; should be excavated to sound material.

CONSTRUCTION MATERIALS: Good source of fill.

ROCK TEST DATA:
Permeability = 0.2 to 3.0 ft/day
Unconfined compressive strength (samples were 2 inches in diameter and 2 inches in height) = 334 to 830 lb/in^2 (dry) (highly decomposed and weathered mica schist)
= 30 to 40 lb/in^2 (wet) (highly decomposed and weathered mica schist)
= 1,255 to 3,830 lb/in^2 (dry) (unweathered mica schist)
Failure load = 59 to 919 tons/ft^2 (hard mica schist)
= 15 to 16 tons/ft^2 (soft mica schist)

REMARKS: Permeability data from SCS; compressive strength data from VU; load test data from Conwell and Company.

ZOOKS CORNER FORMATION (Ꞓzc; included in Ꞓul)

DESCRIPTION: Medium-gray, very finely crystalline dolomite; silty and sandy; some shaly beds; laminated; minor amounts of medium-gray limestone; total measured thickness is 1,550 to 1,600 feet; type section is along Conestoga Creek, one-half mile west of village of Zooks Corner, Lancaster County.

BEDDING: Thin to thick bedded; includes cross laminae, ripple marks, mud cracks, and graded bedding.

FRACTURING: Joints have a blocky pattern; moderately to well developed; fairly regularly spaced; steeply dipping; most are open but many are filled with calcite.

TOPOGRAPHY: Rolling valley of low relief; gentle and stable natural slopes.

DRAINAGE: Good surface drainage; subsurface drainage is present.

POROSITY AND PERMEABILITY: Openings along bedding, cleavage, joint, and fault planes provide a low to moderate secondary porosity; moderate to high permeability.

GROUNDWATER: One of the lower yielding carbonate-rock aquifers in Lancaster County; median yield is 6 gal/min; yields of over 1,000 gal/min have been reported.

EASE OF EXCAVATION: Difficult; fast drilling rate.

CUT-SLOPE STABILITY: Good.

FOUNDATION STABILITY: Good; thorough investigation for solution cavities should be undertaken.

CONSTRUCTION MATERIALS: Good source of road material, riprap, embankment facing, fill, and aggregate.

ZULLINGER FORMATION (Єz)

DESCRIPTION: Interbanded medium-gray limestone and dolomite; interlaminated limestone and dolomite; thin dolomite; local thin quartz-sand beds; probably 2,500 feet thick; type section is in roadcuts at Wayne Castle on Pa. Route 16, 3 miles west of Waynesboro, Franklin County.

BEDDING: Well bedded; thick to massive.

FRACTURING: Joints have a blocky pattern; moderately well developed; moderately to highly abundant; regularly spaced, having a moderate distance between fractures; open and steeply dipping.

WEATHERING: Moderately resistant; slightly to moderately weathered to a shallow depth; irregularly shaped, medium-sized blocks result from prolonged weathering; interface between bedrock and soil is characterized by pinnacles in most places.

TOPOGRAPHY: Rolling valley of low relief; natural slopes are gentle and stable.

DRAINAGE: Good subsurface drainage; little surface drainage.

POROSITY AND PERMEABILITY: Solution channels provide a moderate secondary porosity; moderate to high permeability.

GROUNDWATER: Calculated median sustained yield is 82 gal/min; yielding zones are evenly distributed through the upper 450 feet of bedrock; water is relatively hard.

EASE OF EXCAVATION: Difficult; bedrock pinnacles are a special problem; fast drilling rate; quartz-sand beds slow the drilling rate.

CUT-SLOPE STABILITY: Fair to good.

FOUNDATION STABILITY: Good; thorough investigation for solution cavities should be undertaken.

CONSTRUCTION MATERIALS: Good source of road material, riprap, embankment facing, fill, and aggregate.

Each rock formation in Pennsylvania is an individual unit having a characteristic and often unique set of properties. These properties vary widely, even within a specific geologically identified formation, such as the Martinsburg Formation. In addition to the foregoing summaries, it is always advisable to measure all properties of each rock type encountered during the detailed site investigation.

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GLOSSARY

Albite. A feldspar mineral consisting primarily of sodium-aluminum silicate; common in igneous, metamorphic, and some sedimentary rocks.

Aquifer. A rock unit or group of units that is capable of supplying water to wells in usable quantities.

Argillite. A rock derived from siltstone, claystone, or shale that has a higher degree of induration than is present in those rocks.

Augite. A common igneous-rock-forming mineral of the pyroxene group; dark colored; contains considerable calcium-aluminum, iron, and silica; a common mineral in diabase.

Bedding. In geology, the physical separation within sedimentary rocks along planes of stratification dividing rocks of similar or different lithologies.

Biotite. A mica mineral; a hydrated silicate containing aluminum and iron; typically dark colored (brown to black or green) and occurs in flakes.

Breccia. A rock made up of highly angular, coarse fragments; may be indicative of the presence of a fault.

Calcarenite. A limestone or dolomite rock of coral or shell sand.

Chlorite. A mineral that is tabular or in scales like mica; typically green to black, transparent to opaque; common in metamorphic schists; usually not visible in sedimentary rocks.

Claystone. Rocks that are largely composed of clay and sometimes bound together by iron carbonate; nonlaminated.

Cleavage. In rock, the tendency to split along definite, parallel, closely spaced planes.

Compressive strength. A measure of the resistance of a rock to a force that tends to decrease its volume.

Conglomerate. A cemented clastic rock containing rounded fragments that correspond in their grade sizes to gravel or pebbles.

Density. The mass of a substance per unit volume.

Dip. The angle at which a rock unit is inclined to the horizontal.

Dolomite. A carbonate sedimentary rock containing more than 90 percent dolomite and less than 10 percent calcite.

Effective porosity. A qualitative evaluation of the usable pore spaces in a rock for the transmission of groundwater.

Epidosite. A pistachio green and white, altered igneous rock usually consisting of the minerals epidote and quartz.

Fault. A physical break within the rocks along which there has been movement of the two sides relative to one another.

Feldspar. A general name for a common group of rock-forming minerals of alkali-aluminum silicate composition.

Ferromagnesian. Containing iron and magnesium; usually refers to the silicate minerals in rock.

Fracture. A break in rock caused by stresses.

Gneiss. A banded metamorphic rock.

Groundwater. Water below the water table.

Hornblende. A mineral belonging to the amphibole group; typically black to dark green and commonly prismatic; a silicate of variable composition, which typically contains calcium, sodium, magnesium, iron, and aluminum; most common in igneous rocks and certain gneisses.

Hypersthene. A mineral belonging to the pyroxene group, usually brownish green or grayish black to brown; prismatic or tabular; uncommon.

Interstitial. Existing in or forming an opening.

Intrusion. A body of igneous rock that invades older rock.

Joint. A fracture in rock along which no movement has occurred.

Labradorite. A mineral belonging to the feldspar group; anorthosite is a rock composed largely of labradorite.

Limestone. A rock composed chiefly of the mineral calcite.

Lithology. A description of the composition of rocks.

Mantle. The layer of loose, incoherent rock material, of whatever origin, that nearly everywhere forms the surface of the land and rests on hard bedrock. It comprises rock waste of all sorts, volcanic ash, glacial drift, alluvium, wind-blown deposits, vegetal accumulations, and soils.

Matrix. In rock in which certain grains are much larger than others, the grains of smaller size form the matrix.

Micaceous. "Flaky"; consisting of thin plates as in the mica minerals.

Microcline. A member of the feldspar mineral group containing potassium, aluminum, and silica; usually white, but may be pink or green.

Muscovite. A member of the mica group of minerals; characteristically colorless and in flakes.

Oolitic. Composed of oolites, which are spherical to ellipsoidal bodies.

Oligoclase. A mineral member of the feldspar group that occurs principally in igneous rocks and some gneisses.

Orthoclase. A mineral belonging to the feldspar group; has the same composition as microcline.

Peridotite. An igneous rock consisting largely of olivine; frequently altered to serpentine (a softer mineral); dark colored.

Phenocryst. A porphyritic crystal; one of the relatively large and ordinarily conspicuous crystals of the earliest generation in a porphyritic igneous rock.

Phlogopite. A mineral belonging to the mica group; resembles muscovite in hand specimen; most common in metamorphic rocks.

Phyllite. A metamorphic rock, rich in mica, that has less distinct cleavage and is often finer grained than schist.

Plagioclase. A collective name for a series of sodium, calcium, aluminum, and silicate minerals in the feldspar group.

Plane. A flat or level material surface.

Porphyritic. A rock texture containing large mineral grains among the finer grains; applies to igneous rocks.

Pyroxenite. Any rock principally composed of pyroxene minerals; dark green to black when fresh.

Rebound. The amount of upward movement of a surface that occurs when a load is removed from that surface.

Recharge (intake). The processes by which water is absorbed into a rock formation either directly or indirectly by way of another formation.

Sandstone. Rock composed mainly of aggregates of sand-sized quartz grains.

Schist. A metamorphic rock that has a foliated structure and splits into thin, irregular plates.

Shale. A laminated sediment in which the constituent particles are predominantly of the clay grade; has fissility that is approximately parallel to bedding.

Shearing. The slipping of one part of a rock mass past another.

Shear strength. A measure of the resistance to the slipping of one part of a rock mass past another.

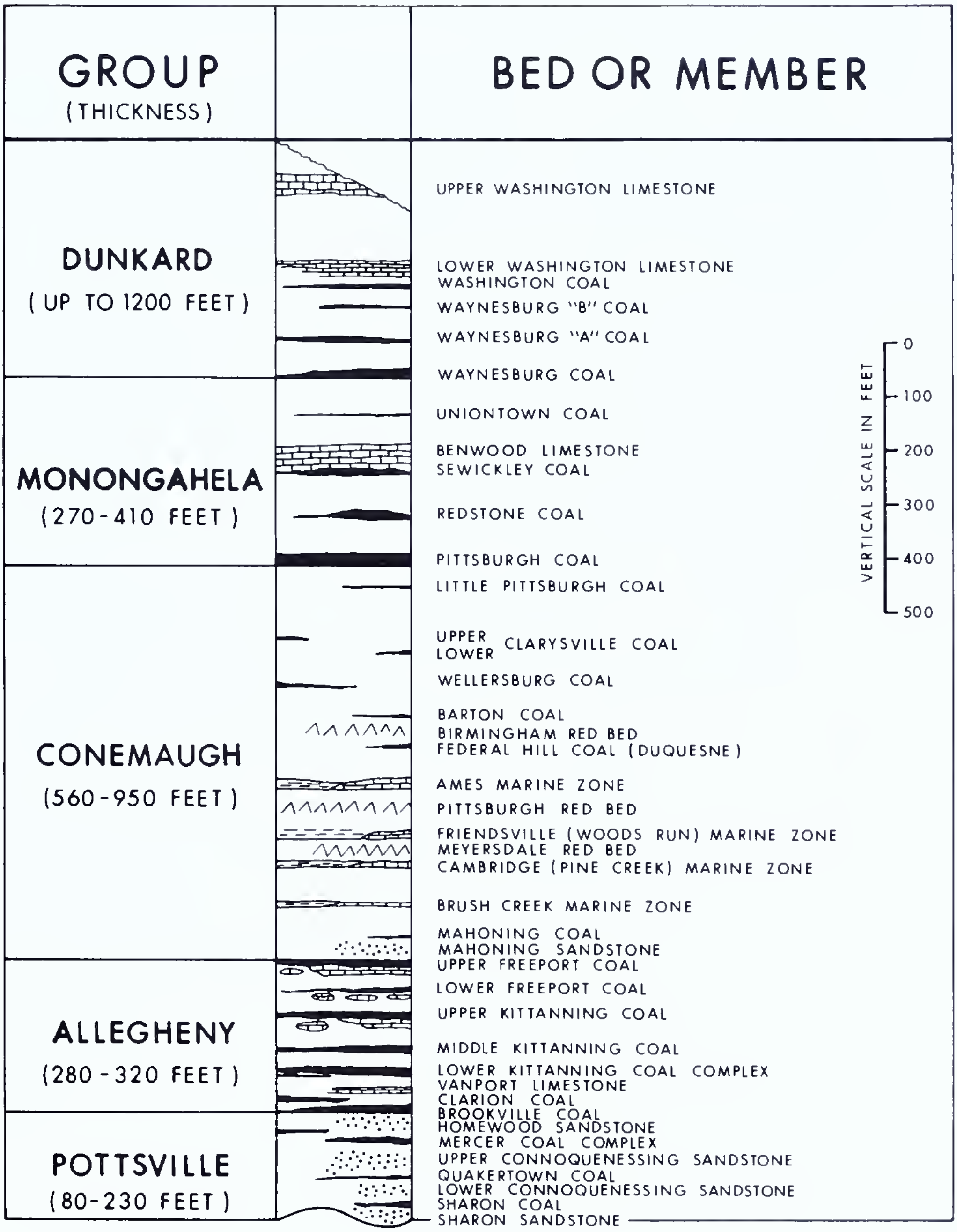
Specific gravity. The ratio of the density of a substance to the density of water taken as a standard when both densities are obtained by weighing in air.

Stromatolites. Laminated but otherwise structureless calcareous objects, commonly called fossil algae.

Tensile strength. A measure of the competency of a rock to resist forces that tend to pull it apart and create cracks and fissures.

Underclay. A nonbedded clay occurring below a coal seam; also called plastic clay or soft clay.

APPENDIX



Generalized section of Pennsylvanian rocks in western Pennsylvania.

SOURCES OF ROCK TEST DATA

Bureau of Mines (USBM), U.S. Department of Interior
E. L. Conwell and Company, Philadelphia, Pennsylvania
Corps of Engineers, U.S. Army, Pittsburgh District, Philadelphia District, and Baltimore District (USCE)
Pennsylvania Department of Transportation, Bureau of Testing, Materials, and Research, and District 8-0 Soils Engineering Office (PDT)
John H. Robinson Engineering, Inc., Erie, Pennsylvania
Soil Conservation Service, U.S. Department of Agriculture, Harrisburg (SCS)
Villanova University, Department of Civil Engineering, Villanova, Pennsylvania (VU)